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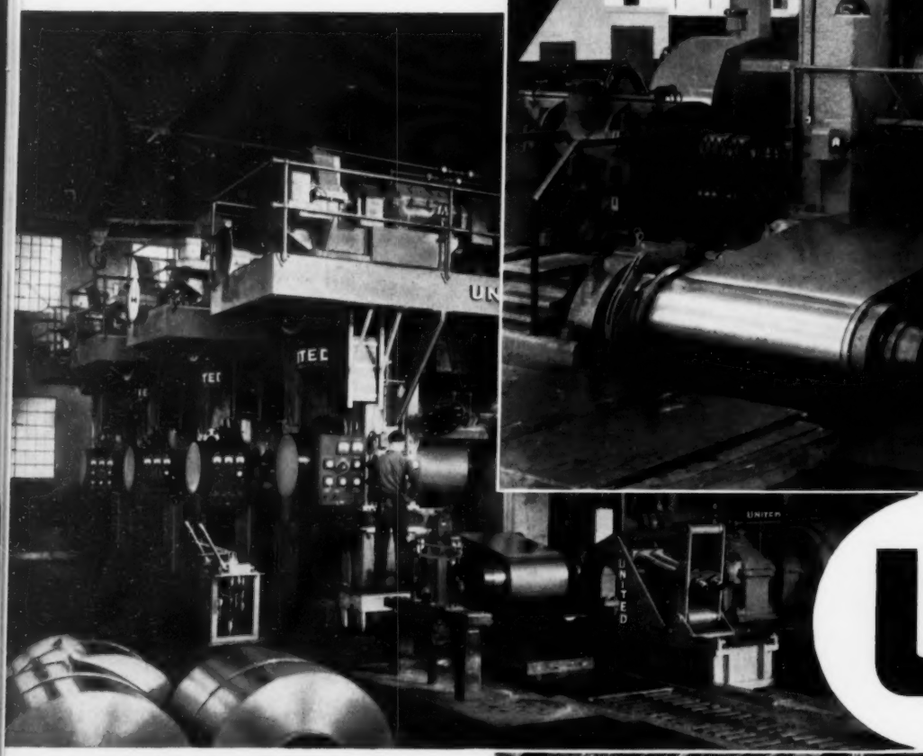

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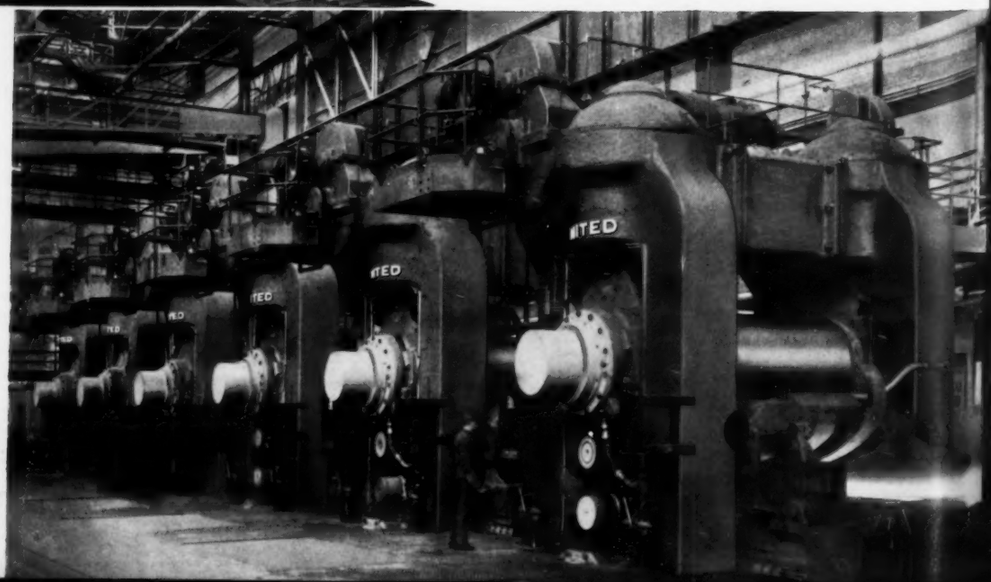

98" Continuous Hot Strip Mill

DETROIT Section of A. I. & S. E.

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Formally Opened Wednesday, June 1, 1938

ON Wednesday, June 1, in the new auditorium of the Detroit Edison Company, over two hundred members and guests of the Association were present for the formal opening of the society's new Detroit section. The addition of this Detroit section now makes a total of six districts in the organization which includes Pittsburgh, Chicago, Cleveland, Philadelphia, Birmingham, and Detroit. That the formal organization of a chapter in the Detroit area will prove beneficial was clearly evident by the enthusiastic group that attended the opening ceremonies of the new section.

Included on the official program which was presided over by Julius A. Clauss, (Shown below, opening the meeting), Chief Engineer, Great Lakes Steel Corporation and founder of the Detroit section, were L. F. Coffin, President of the Association; Brent Wiley, Managing Director; James Farrington, Father of the Association; and W. A. Perry, Second Vice-President. The chairman of the new section, Loyal R. Milburn, Electrical Engineer, Great Lakes Steel Corporation, was officially notified of his office together with E. Weiss, District Manager, Cutler-Hammer, Inc., who was appointed secretary of the section. These appointments were announced by President Coffin who also announced the personnel of the other committees. Moving pictures of the operation of various units of the Great Lakes Steel Corporation as well as recent construction projects were shown. On the following three pages will be found Mr. Clauss' opening remarks as well as illustrations of the new officers and guests.

Above is shown L. F. Coffin, President of the Association, addressing the members of the new Detroit section at which he formally announced the officers for the section. Below is shown a general view of the many who attended the opening session.

INTRODUCTORY REMARKS

By J. A. CLAUSS, Chief Engineer

Great Lakes Steel Corporation

ECORSE, MICHIGAN

Mr. Coffin, Mr. Wiley, members of the Detroit Section of the Association of Iron and Steel Engineers, and friends:

As I look over this audience tonight, I feel somewhat like the young man who courted the lady of his dreams sincerely and ardently through many difficulties and when he saw the lady of his choice approaching, exclaimed: "After long last, behold my heart's desire!"

The forming of this Detroit Section is not a mere passing fancy, the late John F. Kelly discussed it with me many times as far back as 1931. Like the fabled lover who pleaded his cause, I, too, had to pass the scrutiny of a fond and careful parent in the person of our National Officers and Directors.

The presence of you, our National officers, is evidence of the fact that we have your benediction on this Section and I am happy to report to you that this Section will start with a membership of about ninety-five—practically every one of whom I know personally. I know from personal experience that no finer or more capable group of candidates was ever submitted for your favorable consideration.

We extend to you, President Coffin, and to you, Secretary Wiley, a sincere and hearty welcome, we pledge to you a sincere desire to so conduct our sectional business that it will bring credit to our Association and thus prove the wisdom of your decision to inaugurate a Detroit Section of our Association.

I believe that we of the steel industry are engaged in one of the most interesting and fascinating industries. In the short space covering the span of an average lifetime, we have seen this infant industry grow to the proportions of a giant, until today the welfare of our country is dependent to a large extent on the success of the steel industry.

We have seen a host of marvelous electrical and mechanical devices change an industry which depended largely on brute strength for its successful operation become one of the best mechanized industries of our time.

No longer is brute strength the chief requisite in our industry for a job. No longer do we make adjustments to our equipment with a sledge. No longer our "guess" and "by God" methods used in making steel. No, these are things of the past.

Today, trained, intelligent men operate our equipment, precision machinery is the rule rather than the exception, and our steel-making is according to prescription based on a study of all the facts on hand by

Loyal R. Milburn, Electrical Engineer, Great Lakes Steel Corporation and E. Weiss, District Manager, Cutler-Hammer, Inc., will respectively handle the affairs of the Detroit section in the capacities of Chairman and Secretary.

The upper left illustration shows J. Farrington, Father of the Association, addressing the members of the new section. Directly above Brent Wiley, Managing Director of the Society welcoming the new group into the Association. At the right, W. A. Perry, Second Vice President of the Association, made the trip from Chicago to participate in the activities.

men who know what such and such a steel will do under certain known conditions.

I can assure you that as one who has been engaged in the steel industry more than thirty-five years, this marvelous transformation has been most interesting. While the changes in our industry have been rapid and wonderful, I believe still greater changes, far-reaching in their effect on established practice, will be developed in the future.

Right here in the Detroit area in 1863, Bessemer steel was first made in Wyandotte and the man who proposed it was called "crazy". Bessemer steel has been outranked by open hearth and we all know that for quality the electric furnace produces better steel than the open hearth furnace. Each day, new alloy steels are developed—who dares predict when the acme of perfection will be reached.

With the wonderful development of mechanical and electrical equipment has come a still greater problem for the minds of men to solve. The finest piece of machinery we can develop and build is just so much iron and steel without a human operator. Human engineering must now receive the careful consideration of thoughtful men. The engineers and operators of the steel industry have done wonders with things mechanical.

All of our plants have capable and efficient personnel departments charged with the responsibility to look after those things which effect the welfare and happiness of our men.

We must go farther than this, however, we must find out more about human beings. The engineer, trained to study and analyze his problem to its minutest detail, has got to take up the study of *Human* engineering. On all sides there is evidence of an increasing interest and a realization of the seriousness of this problem.

In this Detroit Section, there will be an opportunity for engineers and operators to meet together and discuss the problems of our industry. We will talk about men and machines—What makes them go, and, why do they act so? There will be no lack of interesting subjects. Here with the fellows of your kind, you can talk freely and gain much information that will be helpful to you in your daily life.

I strongly urge you all to attend our sectional meetings, which will begin next Fall. Papers will be read and discussed, which will be of interest to you, and have a direct bearing on the business in which you are engaged.

I would particularly recommend that the younger members of our Section resolve to take an active part in the Sectional meetings. You will find that by preparing a paper or a discussion of some paper to be read, that you will improve your own knowledge of the subject and learn to express your thoughts and think on your feet. The benefits derived from an Association of this kind are in direct proportion to the part and interest you take in it.

Now most of you men know me, I have sung your praises to the National officers and placed you on a high pedestal. Knowing you as I do, I will after tonight retire to the sidelines and watch with interest your progress, confident that the Detroit section will give a good account of itself.

From left to right in the lower left illustration is shown Wilson F. Clemens, Donald E. McGuire, Raymond M. Hughes, L. M. Ripple, and H. W. Osborne, all from the Great Lakes Steel Corporation. These men were very prominent in organizing the new section. In the lower right Mr. Wiley, Mr. Coffin, Mr. Clauss and Mr. Perry gathered for a few words before the opening of the session.

EDITORIAL

The Association's Growing Membership

Much credit is due the membership committee of the Association and the many members who have cooperated closely with them, for the fine record that has already been established this year. As a result of the Committee's efforts to further acquaint the Steel Industry with the purpose, background, and achievements of the Association more than 250 new memberships have been approved by the Board of Directors since the first of the year.

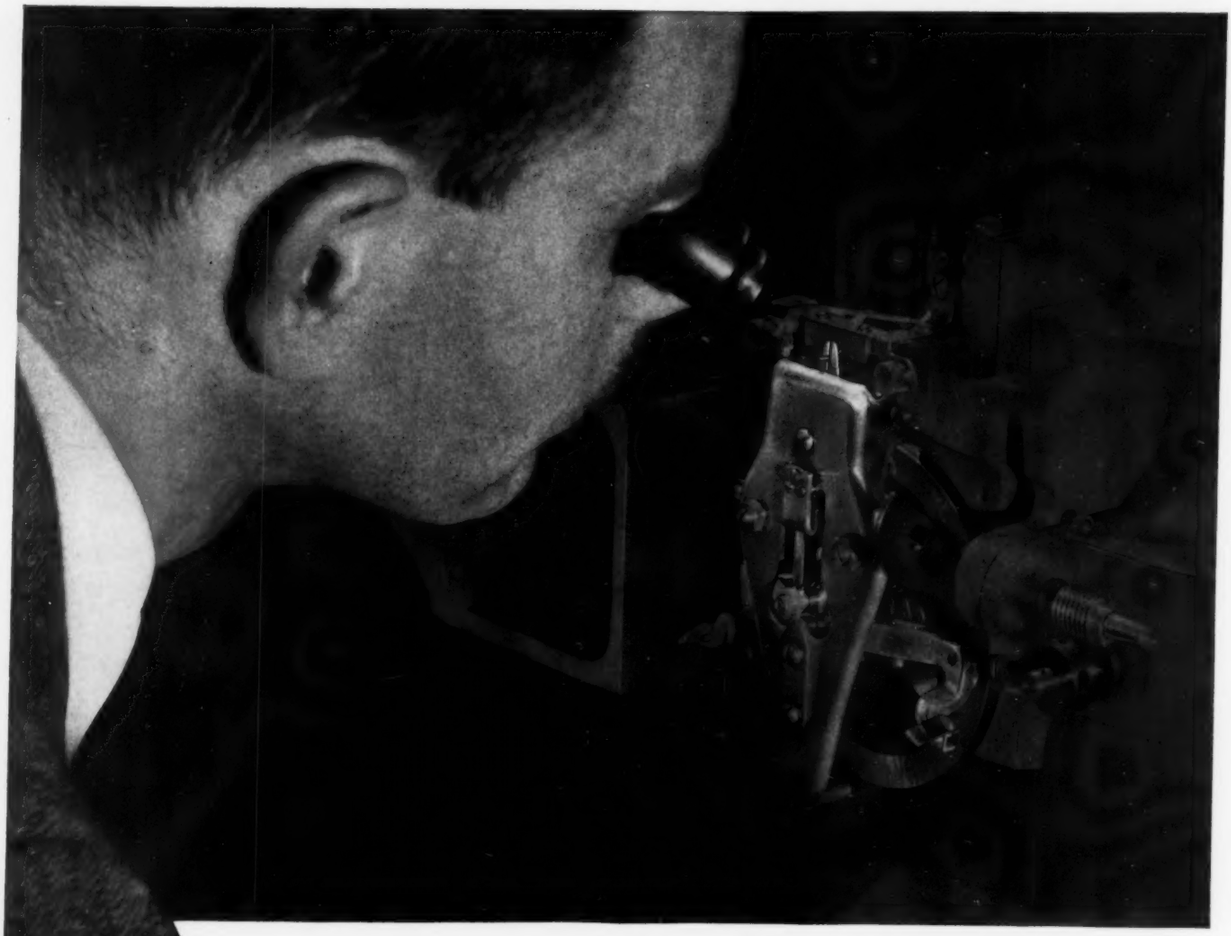
Interest in the Association of Iron and Steel Engineers' activities is also steadily increasing abroad as is emphasized by the growing list of memberships and extension of the Iron and Steel Engineer subscription list which now includes a distribution in twenty-one foreign countries.

Among the recent applicants for membership in the A. I. & S. E. is Mr. A. T. Kathner, Consulting Engineer and Industrial Representative of Siegen, i. W., Germany. Mr. Kathner was located formerly in the United States where he had more than twenty-five years experience in steel mill engineering work, having been identified with Rust Engineering Company, Weirton Steel Company, Follansbee Brothers Company and several other companies.

Mr. Kathner made a recent visit to the United States and the object of his visit was to assist representatives of several foreign steel companies in their inspection of a number of the modern steel mills in the Chicago, Pittsburgh, and Detroit districts, and included in the group were Emil Vorbach, Manager, Prager Eisen Company, Kladno, Czecho-Slovakia; Heinz Humann, Superintendent, Dillinger Steel Works, Dilligen-Saar, Germany; and Erwin Gerlach, Superintendent Sheet Mills, Huta Batory, Poland.

The Iron and Steel Institute of London has announced in their Fall Meeting Circular No. 2 that a number of the representatives of the Iron and Steel Institute and the Institute of Metals are planning to visit Canada and United States early this fall. A very extensive program of visits has been arranged including all of the larger steel plants located in America.

These visits from foreign country representatives is indicative of the great interest the steel fraternity has in the advanced steel mill engineering embodied in the modern design of machinery and improved mill practice developed in United States. To further such improvements in the industry by cooperation of its members is the main purpose of the Association, and its service is gradually being broadened by the growth of membership.



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If you were measuring temperature with a manual potentiometer, you'd try to keep your eye on the galvanometer pointer . . . where Micromax automatically keeps its feelers. You'd try to catch changes at the very start . . . as Micromax actually does.

But, to do a Micromax quality job, you'd need a magnifying glass to see the first minute motions of the pointer. For Micromax sees them while they are still too small for the naked eye . . . and before they would interest any pyrometer but Micromax, it moves indicator, recording pen and (in automatic control) the control valve, feeder or damper.

There is no clearance through which the galvanometer pointer has to move before its motion is acted on. The pointer merely "leans" against the feelers and the effect is as though it leaned directly against index, pen and valve . . . all at once.

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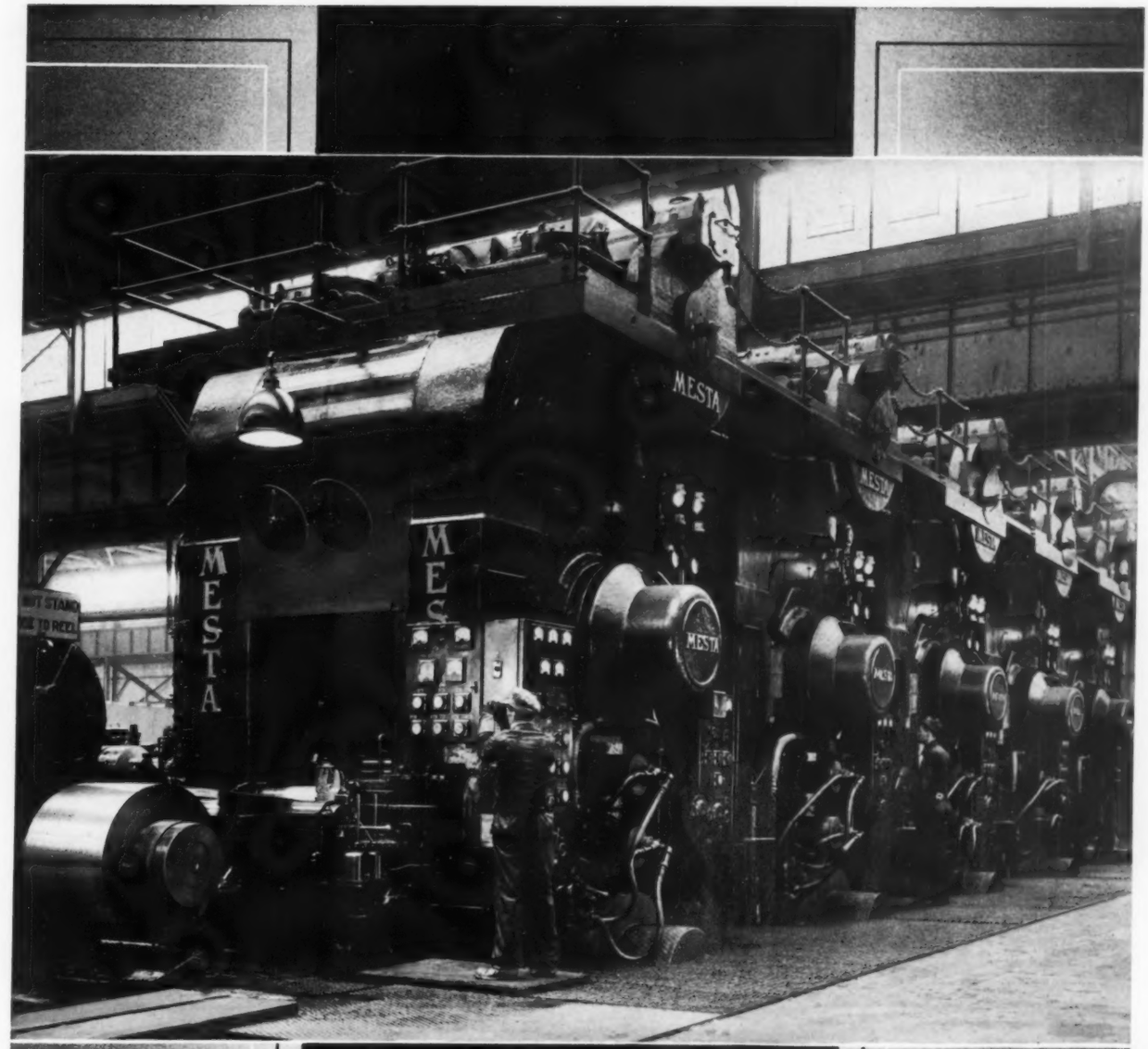


MESTA 5-STAND
TANDEM COLD MILLS
for
ROLLING TIN PLATE

MESTA MACHINE COMPANY, PITTSBURGH, PA.

FIRST Power

By W. E. GUTZWILLER

Electrical Department

Allis-Chalmers Manufacturing Company

MILWAUKEE, WIS.

▲ THE first commercial installations of mercury arc power rectifiers in this country date back to the year 1925. Since then the use of this type of stationary power converting equipment has shown a steady and rapid increase. Today there are over 700,000 kw. of rectifier capacity installed and on order in this country.

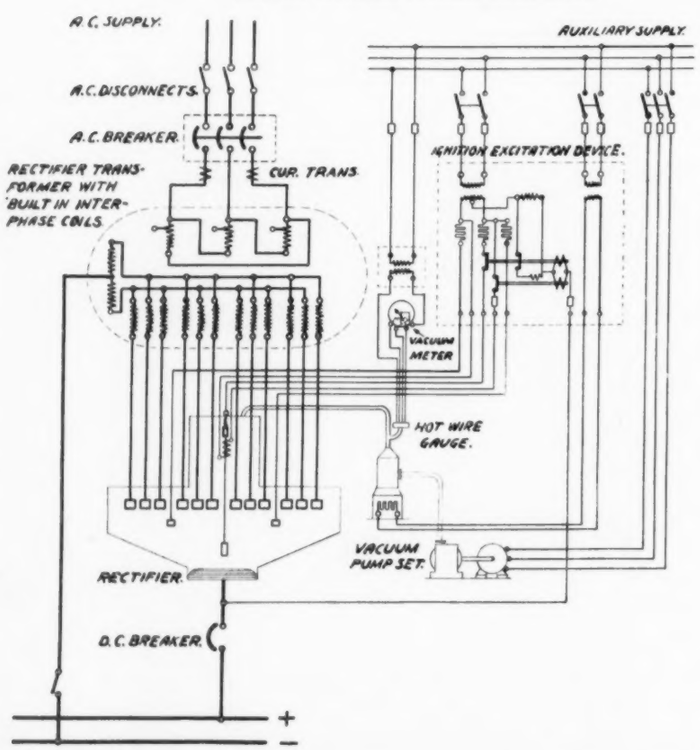
While in the earlier days the application of mercury arc rectifiers was limited almost entirely to electric railways, a rapid shift towards the industrial fields has taken place in recent years. This is no doubt due to the many improvements made in the design and manufacture of rectifiers and their auxiliary apparatus. One of the developments which has mainly contributed to the use of rectifiers in industrial fields is the electronic control grid which permits the control of the rectifier output over a wide range with relatively simple and inexpensive means. The major industrial uses of mercury are power rectifiers have so far been in the electrolytic industry. Approximately seventy-five per cent of the power rectifiers purchased in this country within the last three years were for electrolytic plants.

A year ago the mercury are rectifier definitely entered the steel mill field with the installation of a 1000-kw., 250-volt rectifier unit. The company which deserves credit for this pioneer installation is the Republic Steel Corporation.

HISTORY

Early in 1936 the Republic Steel Corporation started work on a new wire mill, with a ground area of 177,000 sq. ft. Although to be located within some 1000 ft. of their existing South Chicago works, the new wire mill was to be a separate, self-contained manufacturing unit, using processes for wire making which were new in many respects. The electric power for this new mill was to be purchased from the local utility company. The entire requirements for both a-c and d-c power were to be supplied from a centrally located converting and distributing substation. Due to the distance between other substations and the new mill, no tie with the existing 250 volt d-c mill system was to be provided.

FIGURE 1—A-c and d-c connections of the rectifier unit and the essential rectifier auxiliaries.



TYPE OF LOAD

Approximately one-half of the wire mill load consists of a-c motors which are extensively used for driving nail machines. The remainder of the load is supplied in the form of 250-volt d-c and is used wherever smooth acceleration and a wide speed range are required, particularly for continuous wire drawing machines. Direct current is also employed extensively for cranes, lifting magnets and other types of material handling equipment, also for all the excitation requirements of four 15,000 ampere, 7-volt synchronous motor-generator sets in the electro galvanizing plant.

After considerable study of the advantages and disadvantages of the mercury arc rectifier, as compared with converting equipment of the rotating type, and after having visited several railway rectifier installations in the Chicago district, the Republic Steel Corporation decided in favor of the rectifier. A 1000-kw., 4000-ampere, 250-volt rectifier unit was chosen, capable of carrying 125 per cent load for two hours and 200 per cent load for one minute.

REASONS FOR CHOICE OF MERCURY ARC RECTIFIER

The nature of the load and the provision for future expansion of the new wire mill largely contributed to a condition of low load factor. This load factor, with the first unit of the new mill completed, was calculated to be approximately 30 per cent of the rectifier rating. Due to the relatively high efficiency of the rectifier at partial load, it was estimated that with power purchased

RECTIFIER *in an* AMERICAN STEEL MILL

Presented before the A. I. & S. E. Philadelphia Section, Saturday, November 6, 1937

at approximately 6 mills the installation of a rectifier would result in a yearly power saving of approximately $1500.00, as compared with a motor-generator set.

The substation of the wire mill, besides housing the converting equipment, was to contain only stationary apparatus such as transformers, switchgear, control and metering equipment, which do not require a regular attendant. The rectifier, being a static converter and requiring little attendance and maintenance, fit this layout admirably.

Very close voltage control over a wide range, with quick response, was essential for the converting unit, due to the requirements of the wire drawing machines and of the excitation of the machinery in the automatic galvanizing plant. It was found that the electronic grid control on the rectifier would fully meet these requirements. The grid control was to be arranged to automatically compensate for a-c and d-c feeder voltage drop and for the inherent machine regulation.

Due to the cooling of the rectifier by water, no special provision for forced substation ventilation or air filtering equipment had to be made. The rectifier station can be kept practically closed, avoiding infiltration of mill dust and acid fumes from the cleaning house and electro-galvanizing department.

POWER SUPPLY

Primary power for this new mill is obtained from the local utility through three 6000-kva, 60-cycle transformer banks, stepping down the incoming voltage from 13,200 to 2300 volts in an outdoor substation some distance away. This substation supplies the entire South Chicago Works. Two 600,000 c.m. 3-conductor underground cables run to the substation of the wire mill, from where the power is distributed, part at 2300 or 440 volts,—the latter voltage being obtained from a 1000-kva transformer bank,—and part converted to 250 volt d-c by the rectifier.

STAND-BY EQUIPMENT

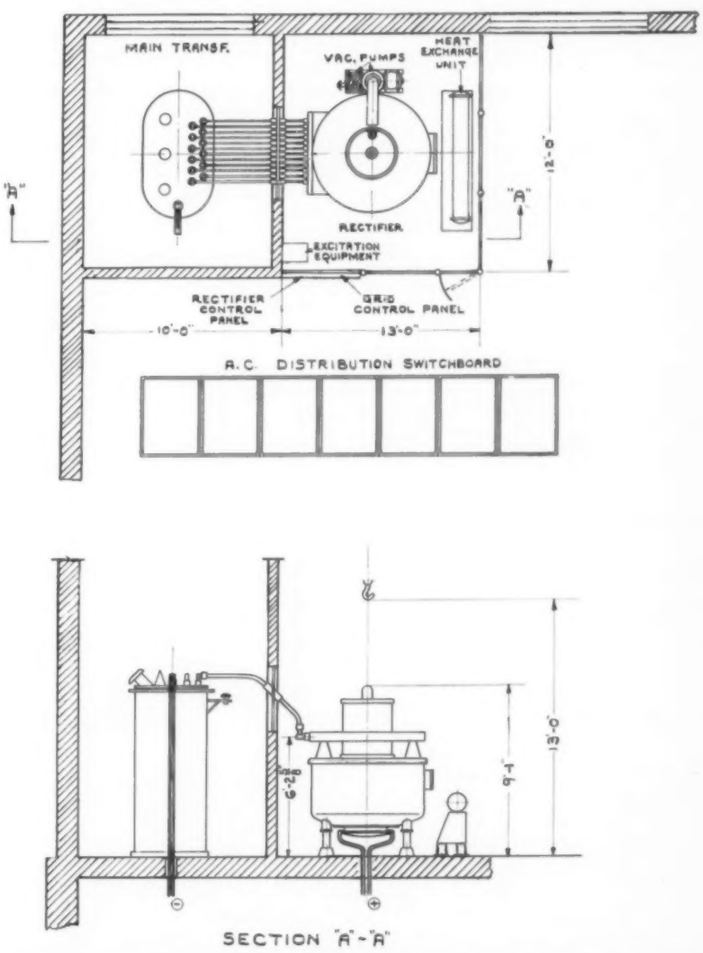
Provisions are made so that in emergency a 500-kw motor-generator set located in a scrap preparation yard some 600 ft. from the rectifier substation can be used as stand-by equipment for the rectifier. For this purpose a light feeder is brought from the motor-generator set into the rectifier substation.

CONNECTION DIAGRAM OF RECTIFIER SET

Figure 1 shows the a-c and d-c connections of the rectifier unit, as well as those for the essential rectifier auxiliaries. The 2300 volt, 3-phase, 60-cycle power is taken through a cubicle type switch unit, to the rectifier transformer, where it is changed from 2300-volt, 3-phase, to 6-phase, 236-volt phase-to-neutral voltage. The secondary winding consists of four wye systems with the neutrals paralleled through interphase coils, the mid-point of which forms the negative terminal of the rectifier unit. The transformer is rated 1200-kva and is of the oil insulated, water-cooled indoor type. The secondary windings are connected to the respective anodes of the rectifier. On the d-c side of the rectifier a single-pole solenoid-operated 6000-ampere semi-high speed d-c breaker is provided in the positive lead and a 6000-ampere d-c knife switch in the negative lead.

The essential rectifier auxiliaries, such as ignition-excitation devices, vacuum measuring equipment and

FIGURE 2—Simplified layout of the rectifier unit.



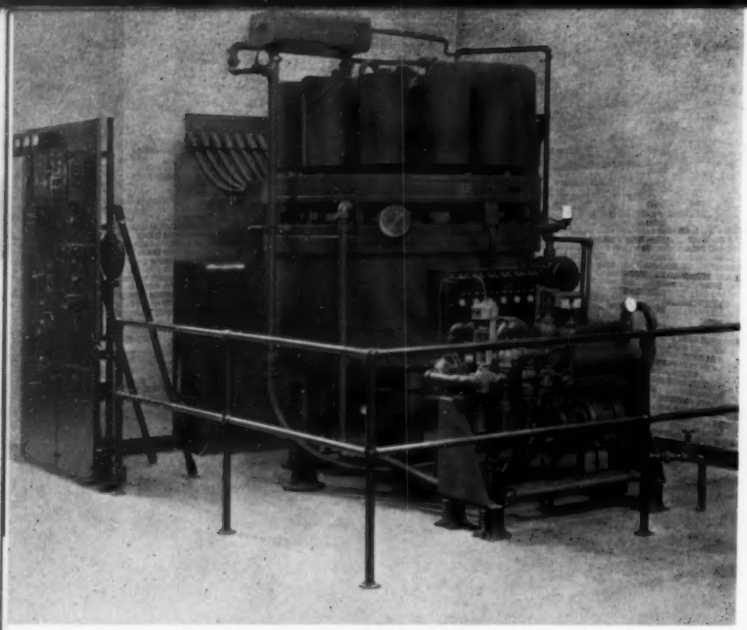


FIGURE 3—The rectifier tank with its auxiliaries and control panels.

vacuum pumps, are supplied from a 2300/230/115 volt control transformer bank, consisting of three 3-kva single-phase transformers.

STATION LAYOUT

Figure 2 shows a simplified layout of the rectifier unit. Figure 3 shows the rectifier tank with its auxiliaries and control panels. On account of dust and acid fume conditions, and also due to the fact that the plant is built on filled-in swamp land, all substation equipment was installed indoors. The rectifier transformer is located in a fire-proof compartment in the corner of the substation building. The rectifier tank, which has twelve water-cooled, grid-controlled anodes, is installed adjacent to the transformer compartment. As a result, the twelve anode cables can be kept very short, and do not require special supports.

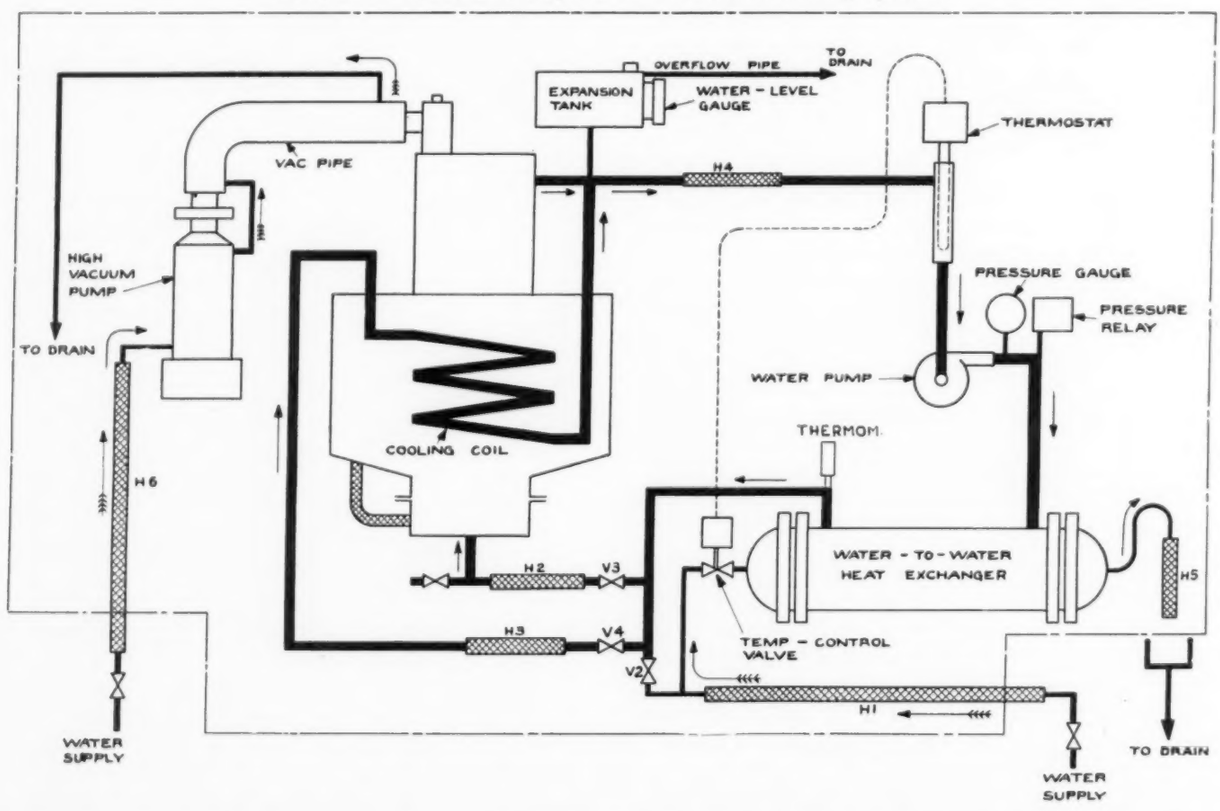
Since the rectifier tank, vacuum pumps and cooling equipment are at approximately positive rectifier potential, a protective railing has been provided to surround them. The floor space requirements for the rectifier tank and its auxiliaries are approximately 12 ft. x 13 ft., and for the rectifier transformer, approximately 10 ft. x 12 ft. The maximum head room for untanking the rectifier is 13 ft.

The two rectifier control panels are located adjacent to the rectifier. The positive, or cathode, lead from the bottom of the rectifier, as well as the negative lead leaving the rectifier transformer, are taken through the floor into the basement, where the d-c switchgear is located.

COOLING EQUIPMENT

Due to the corrosive action of the mill water, and the large amount of suspended matter in it, direct cooling of the rectifier was not considered safe, and a water-to-water heat exchanger was therefore provided.

FIGURE 4—Schematic diagram of the rectifier cooling system.



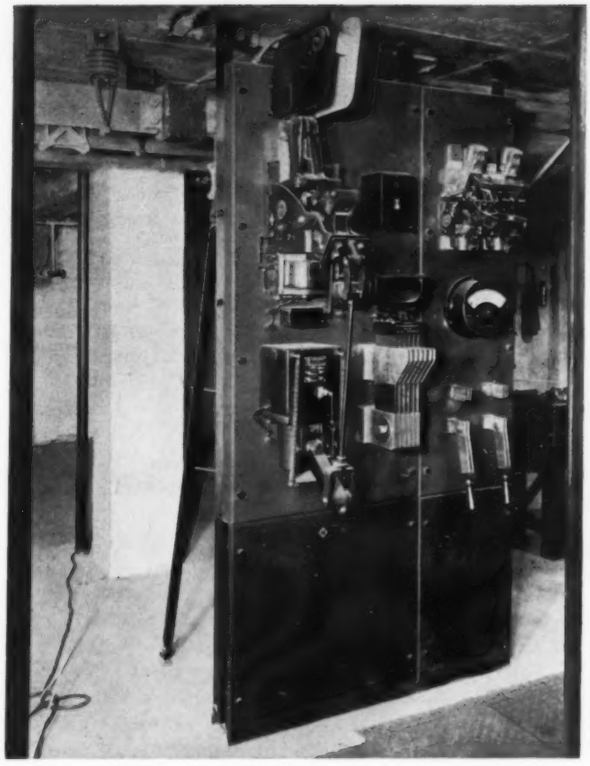


FIGURE 5—The d-c breaker panels shown here are located in the substation end of the distribution tunnel.

This heat exchanger with lts accessories is shown in the foreground of Figure 3. It consists of a bundle of tubes connected in parallel between two headers, enclosed in a cylindrical cast iron shell. The mill water flows through the tubes between the headers, while the soft or rectifier water flows through the shell. Figure 4 shows a diagram of the rectifier cooling system. The rectifier cooling water, which is chemically treated to prevent corrosion, is recirculated in a closed system between the rectifier and the heat exchanger by means of a motor driven water pump. This closed circuit is indicated by heavy lines.

The mill water flows through the heat exchanger tubes and is discharged to a drain. The flow of mill water is regulated by means of a thermostatic type regulating valve located in the mill water inlet. The thermostat, which is located in the water discharge from the rectifier cooling jacket, automatically maintains the water in the recirculating system at a temperature which is best for the operation of the rectifier. The high vacuum pump, which is of the mercury vapor type, is cooled directly by mill water. The rectifier transformer, which is also water cooled, has its water flow regulated automatically by a valve similar to the one used on the rectifier. This regulator, as well as its associated hand valves, thermometers and water drain, are located in the rectifier room.

The cooling equipment for this rectifier unit is designed to dissipate the losses of the equipment when carrying 125 per cent load continuously with a maximum mill water temperature of 80° F. at the inlet. The water consumption of the rectifier tank at full load is approximately 32 gallons per minute, and of the transformer, approximately 9 gallons per minute.

Inasmuch as the cooling water supply is as essential for continuity of service of the rectifier as the power supply, the question of reliability of the water supply from the mill system was seriously considered. A study, however, revealed that the water supply system of the plant was also being used for cooling furnace walls and doors, bearings of roll stands, etc., where a failure of cooling water would affect the operation as much as the failure of the 250-volt d-c power. During the first year of operation of this rectifier unit there has not been a single rectifier interruption due to the water supply. This would indicate that the mill water supply system can be relied upon for cooling rectifier equipment.

PROTECTION AND CONTROL

The rectifier unit is provided with the necessary control and protective apparatus for unattended operation. The unit is started up and shut down by means of push button control in the substation. An alarm annunciator sounds an alarm in the mill and trips the a-c breaker if—

a. The temperature of rectifier anode plate is excessive.
b. The temperature of rectifier transformer is excessive.
c. The gas pressure in the rectifier is abnormally high.
d. The mill water supply fails.

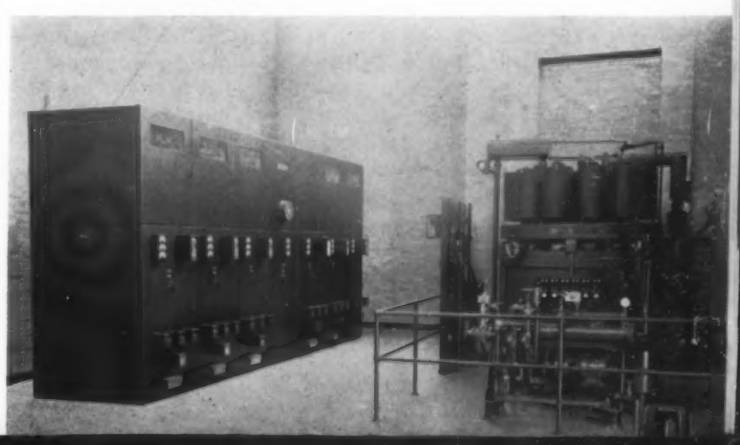
The rectifier d-c breaker is tripped if the water pressure in the recirculating system is low.

The vacuum in the rectifier is automatically maintained at the proper value by means of a contact-making vacuum meter which controls the vacuum pumps.

The d-c voltage of the rectifier is automatically controlled by electronic grids and a rheostatic type regulator. This regulatpr maintains constant voltage at all loads on the 250-volt mill bus, some 750 ft. from the substation. This is accomplished through a pair of pilot wires which carry the bus potential from the load center back to the regulator in the substation.

The grid voltage regulator is of the rocking contact type, which requires no maintenance. Since the plant was started up a year ago, the cover over this regulator has never been opened for inspection. The regulated voltage can be adjusted by means of a hand-operated

FIGURE 6—The cubicles shown below, control eight circuits including the 2300 volt motor-generator sets in the galvanizing plant.



rheostat throughout the range of 240 to 260 volts. Provisions are also made for controlling the voltage of the rectifier manually, and for paralleling the rectifier at a later date with either motor generators or other rectifier equipment.

D-C DISTRIBUTION

Instead of bringing the d-c feeders back to the substation from the load centers, the rectifier is connected to a 9 in. copper channel bus, ½ in. thick, the largest ever rolled, which carries the entire rectifier output to the important distribution centers. All d-c feeder breakers are tapped to this bus, which is carried in a distribution tunnel under the mill. The substation end of this tunnel forms the basement under the rectifier, and contains the rectifier d-c breaker panel, as well as a small panel through which the 500-kw yard motor generator, mentioned above, can be connected to the mill bus. The d-c breaker panels are shown in Figure 5.

A-C DISTRIBUTION SWITCHBOARD

The a-c switchgear consists of seven cubicle-type switch-gear units, as shown in Figure 6. The breakers have an interrupting capacity of 250,000 kva, and the cubicles are equipped with a-c disconnects, as well as with current and potential transformers for metering the protection. The a-c disconnects are of the Isolator type instead of the conventional blade type. The Isolator type affords greater protection to the operator, as all its live parts are enclosed or recessed in orifices, making it impossible for the operator to come in contact with live parts.

Referring to Figure 6, the cubicles, seen from right to left, control the following circuits: Rectifier unit, 2300-volt feeder to yard substation, incoming a-c feeder, substation auxiliaries, 1000-kva, 2300/440 volt transformer bank, lighting feeder, 2300-volt motor-generator sets in galvanizing plant.

ATTENDANCE

During the first year of operation the rectifier has been in operation for twenty-four hours daily. It is usually shut down only over week-ends and holidays. During the day an attendant visits the substation about every three hours. From 5:00 p.m. to 7:00 a.m. the station operated without attendance or inspection.

MAINTENANCE

The maintenance of this rectifier unit during the first year of operation has been negligible, and the set has had no outage due to failure of the rectifier or auxiliaries. The oil in the rotary vacuum pump was changed once, requiring approximately two gallons of new oil. There was also used a small amount of make-up mercury for seals. This, as well as the pump oil, was furnished as part of the original equipment.

On one occasion some irregularities in the operation of the high-vacuum pump were discovered. Upon inspection it was found that considerable sludge had accumulated in its water jacket, which reduced the efficiency of this pump. The cooling system of the pump was cleaned out over the week-end, without causing a forced shut-down of the system. Some minor changes in the cooling arrangement of this pump are now being considered, to prevent this condition in the future.

OPERATING RECORD

By April 1, 1938, the time-meter on the rectifier recorded a total of 10000 operating hours since the rectifier was put in commercial service. At the same time, the a-c watthour meter on the unit indicated that a total input of 1,735,800 kw-hours. Taking into account the conversion losses, this would indicate that the average d-c load of this set has been approximately 151 kw, equivalent to approximately 15.1 per cent load factor. This relatively low load factor is due to the fact that the present unit of the wire mill has not yet attained capacity operations.

Based on the guaranteed overall efficiency, and with the above load factor, the use of the rectifier during the first 17 months operation, has resulted in a calculated power saving of approximately $2600.00 over a conventional synchronous motor-generator set.* The power factor of the rectifier set is estimated to vary between 85 per cent and 93 per cent, lagging, depending on the amount of grid control used. The higher value of power factor applies to the higher loads. No objection has been raised to the lagging power factor of the rectifier as there is ample synchronous motor capacity available in the electro-galvanizing department for power-factor correction.

FIRST COST

It was estimated that the first cost of the rectifier equipment would run somewhat higher than a motor-generator set of the same capacity, but the estimates show that the installed cost of the rectifier, including building and installation material, figures approximately 10 per cent lower than the overall installed cost of a motor-generator set. This is due to the fact that no special foundations, ventilating or air filtering equipment were required for the rectifier. Furthermore, the expensive starting gear commonly used for steel mill synchronous motor-generator sets could be dispensed with.

CONCLUSION

The rectifier unit described in this article has, during the first year of operation just completed, met the requirements for mill supply and has fulfilled all expectations. Considering the excellent operating record of this first steel mill installation, and the rapid progress made in recent years in the design and manufacture of rectifiers, particularly in the control of the rectifier output, and the development of inverted operation of rectifiers for regenerative braking, the day should not be too far distant when mercury arc power rectifiers will supply direct current to main roll drives in this country. Since, for such drives, voltages of 600 volts and higher are already commonly used, the rectifier will show even greater overall economies for such applications than when used on 250-volt mill supply systems.

*Rectifier overall efficiency: 87 per cent at 154 kw.; motor-generator overall efficiency: 72 per cent at 154 kw.

Power Tubes

DESIGN *and* APPLICATION PROBLEMS

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SCHENECTADY, N. Y.

Presented before the A. I. & S. E. Philadelphia Section, Saturday, November 6, 1937

▲ IRON and steel engineers have a two-fold interest in the subject of power tubes. In the first place, modern power tube design trends toward the use of metal construction. In the second place, there are many potential uses for suitable power tube equipment in the steel industry.

DEFINITION AND RELATION TO TANK EQUIPMENT

It may be well first to define what is meant by power tubes and to describe how they relate themselves to other electronic apparatus such as tanks. By broad definition a vacuum tube is an evacuated enclosure through which current is carried by means of electrons or ions. However, tubes are usually permanently sealed-off and are usually built as single-anode units. This is in contrast with multi-anode continuously pumped tanks. From the standpoint of size, power tubes may be considered to fall in the range from 25 amperes to several hundred amperes per anode.

The choice between tubes and tanks is largely an economic one. Tubes could, with sufficient development, be built for any size of apparatus, and of course small tanks have already been made. The economic dividing line between the two types depends upon several factors. One advantage for tanks is low maintenance while tube equipments usually have lower first costs. The write-off period for a given equipment is therefore a big factor. Tubes have always had this advantage when used for radio rectifiers because of high equipment obsolescence in this industry. Sealed-off units eliminate the fixed cost of a pumping system although this is a decreasingly important factor as the sizes increase. Where extreme dependability of service requires spare equipments, replaceable tubes have a real advantage as low cost spares can be switched into the circuit instantaneously if necessary.

Thus, it can be seen that tube and tank equipments are supplementary rather than competitive.

GLASS VS. METAL—DESIGN

One forefather of the vacuum tube is the incandescent lamp which of necessity required a glass envelope. Radio and early industrial tube designs automatically utilized lamp factory technique and with it the glass envelope even though the specific need for this no longer existed. As tube sizes became larger and the need for sturdiness greater, the limitations of this construction both from the standpoint of manufacture and design became increasingly apparent.

Glass designs in the larger sizes are inherently complicated which is a serious drawback with vacuum tubes as repair during manufacture is difficult. The slightest defect may result in the loss of the entire tube. Glass blowing is expensive and exhaust of large glass tubes cumbersome. From the design standpoint it is difficult to support the elements sufficiently well to obtain sturdy tubes. Although the glass envelope itself is much stronger than is usually realized the psychological effect is none too good in the industrial field.

Several years ago two new factors entered the picture. First, seam and spot welding had been made so accurate and reproducable that metal joints could be made vacuum-tight. Vacuum tubes for the control of the welding power made this possible. Second, new alloys, such as fernico, having expansion characteristics almost identical with suitable glasses gave sturdy, inexpensive seals not available before.

By utilizing these two fundamental developments, it has been possible to design essentially all-metal tubes, the only glass being that necessary for insulation. Two are shown in Figure 1. Envelope joints up to two inches in diameter are closed by spot projection welds while larger joints utilize seam welding.

There are two general types of seals used in these metal tubes. See Figure 2. First, the concentric type consists of a fernico lead through the center of a fernico eyelet. The space between is filled with glass and a pant leg of glass may be added for higher voltages. This seal is inexpensive and sturdy, but is not suitable for the higher currents due to the resistance of the

fernico lead, and it is also limited in voltage due to the creepage distance.

The second, or pillar-type seal, consists of a glass tube with a cap at one end and a flared collar at the other, both of fernico. Copper leads are brought to each side of the cup thus providing a low resistance path. The glass can be made long enough or corrugated for any desired voltage rating. In welding control thousands of amperes are being carried regularly through seals of this type.

Metal tubes can be made stronger and more simple than glass tubes. Expensive and often unsatisfactory bases and sockets can be eliminated. Space requirements are also somewhat less.

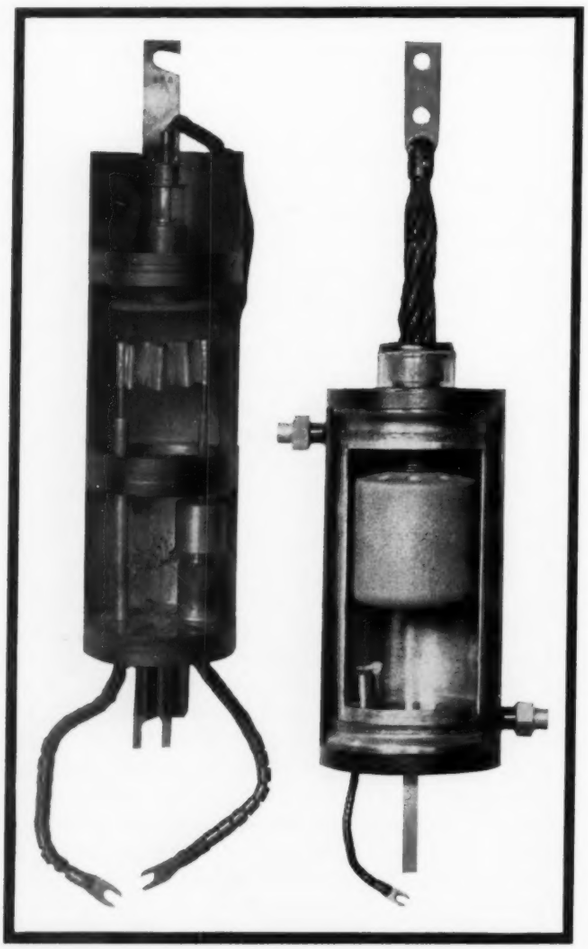
GLASS VS. METAL—MANUFACTURE

Perhaps the greatest advantage of this metal construction lies with the manufacturing processes. Both the seal making and the welding are procedures requiring non-skilled labor and standardized parts. This is in great contrast to elaborate glass blowing which often assumes the aspect of a religious rite.

The exhaust of glass tubes is difficult, requiring elaborate bakeout ovens and expensive high-frequency heating power. With metal designs the tube is its own bakeout oven, and inexpensive electric or gas heating is used. The entire tube is brought to a bright red heat, with the exception of the actual seals, and gas is driven from all parts simultaneously and pumped out. In glass tubes there is a tendency to chase the gas from one part to another due to the difficulty of heating all parts at once.

Economically, the value of these factors becomes greater, the larger the tube size. Medium size tubes are somewhat less expensive than the corresponding glass type while with the larger ones the differential in cost is much greater.

FIGURE 1—Two designs of all-metal tubes. Glass is used only where necessary for insulation.



CATHODES

Another definite trend is toward the use of mercury pool cathodes instead of hot cathodes. All tubes require a source of electrons. In the hot-cathode type this consists of a heated surface which in power tubes is coated with an electron-emitting material. In the pool cathode electrons are made available by an arc on the surface of the mercury. This type of cathode has been used for years in large tank rectifiers and is particularly adapted to power uses because of its ability to withstand overloads and short circuits. New methods of starting and maintaining the mercury arc make pool tubes of recent design instantaneous starting and simple to operate. Hot cathodes are, however, still suitable for tubes up to about 25 amperes average anode current and for some special applications of larger sizes.

HALF-WAVE DESIGNS

Both the older hot-cathode tubes and the newer pool-cathode types are usually half-wave tubes. This tends toward simplicity of design and fewer types as a varying number of one type may be used in different circuits to obtain a large range of power outputs.

WATER COOLING

Water cooling is of great advantage in extending the rating of the larger size tubes. While sealed-off air-cooled pool tubes can be built, their size at present is several times that of the water-cooled tubes and they are therefore uneconomic on the basis of replaceable units. The economic advantage of the water-cooled tubes may be credited to the metal construction as it is impossible to water cool glass tubes adequately. Stainless steel for the body and water jacket of tubes has made possible the use of untreated water where desirable.

TUBE RATINGS

A brief summary on the method of rating tubes may be of interest. Average current is used rather than rms, because with a practically constant voltage drop across the tube the average values of current are the

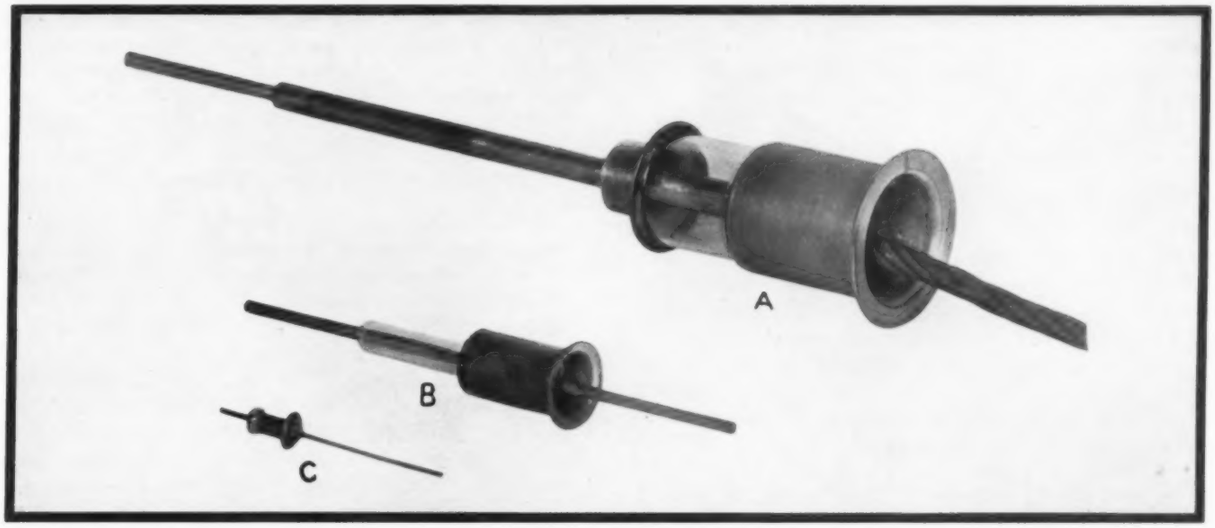


FIGURE 2—This shows the general types of seals used for the all-metal tubes shown in Figure 1.

measure of heating. In addition, peak current ratings are used to indicate the maximum safe instantaneous current that can be carried. This rating is particularly important on hot-cathode tubes as it places a safe limit on cathode emission. The voltage rating generally used is peak inverse voltage, it being the maximum instantaneous voltage a tube will stand in the inverse direction.

Tubes themselves are logically maximum-rated devices. Due to their low thermal capacity in comparison with rotating machinery or even tanks, overload values result in the corresponding maximum temperature in a few minutes. This means that a 5-minute overload may have the same effect as an hour overload on a motor generator set. In applying tubes these ratings are usually translated into normal kw. and percentage overload ratings, de-rating of the tube for normal operation being necessary where long overload ratings are required.

APPLICATIONS—GENERAL

From a technical standpoint vacuum engineers are in a position to attempt any power control or conversion problem. However, from an economic standpoint many of these applications are not justified at the present time.

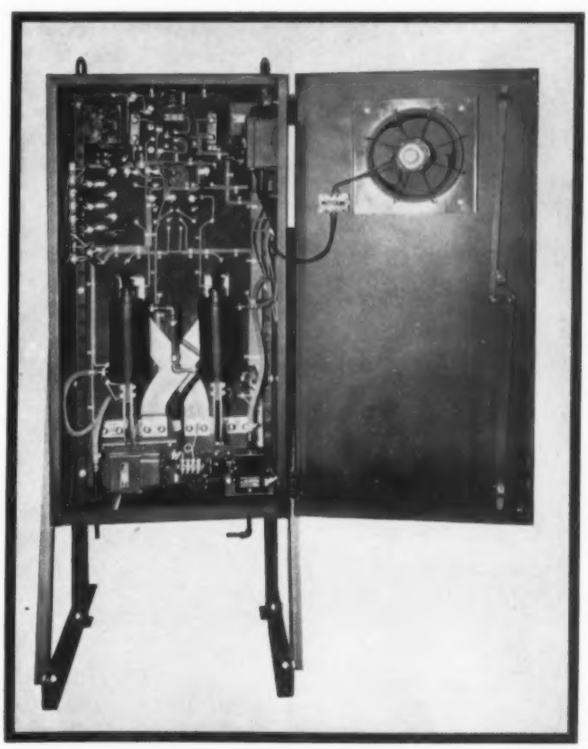
WELDING CONTROL

One field of application that has already attained some importance is that of resistance-welding control. See Figure 4. While this is not a power application by function, it can certainly qualify as such on the basis of size. Peak currents of several thousand amperes and average currents of several hundred are not uncommon. In this application two half-wave tubes act as a switch in the power supply and are timed to give any required number of cycles necessary to make the weld.

As water is necessary for the larger welding electrodes, it is available for cooling the tubes. As water-cooled tubes are much smaller and less expensive for a given rating, most welding control tubes are of that type. So far the use of this control has been justified on the basis of improved welding. However, as tube costs come down it should be possible to show lower overall costs than can be obtained with contactors; realization of this object will greatly broaden the market for these tubes justifying their use even where the improved welding is not required.

Large radio transmitters require as much as 1500 kw at from 10,000 to 20,000 volts. Hot-cathode tubes

FIGURE 3—Rear view of control panel for resistance welding application.



have given a good account of themselves in this service although tests indicate that pool tubes can handle this application more economically in the larger sizes. An installation of the pool type is now being made.

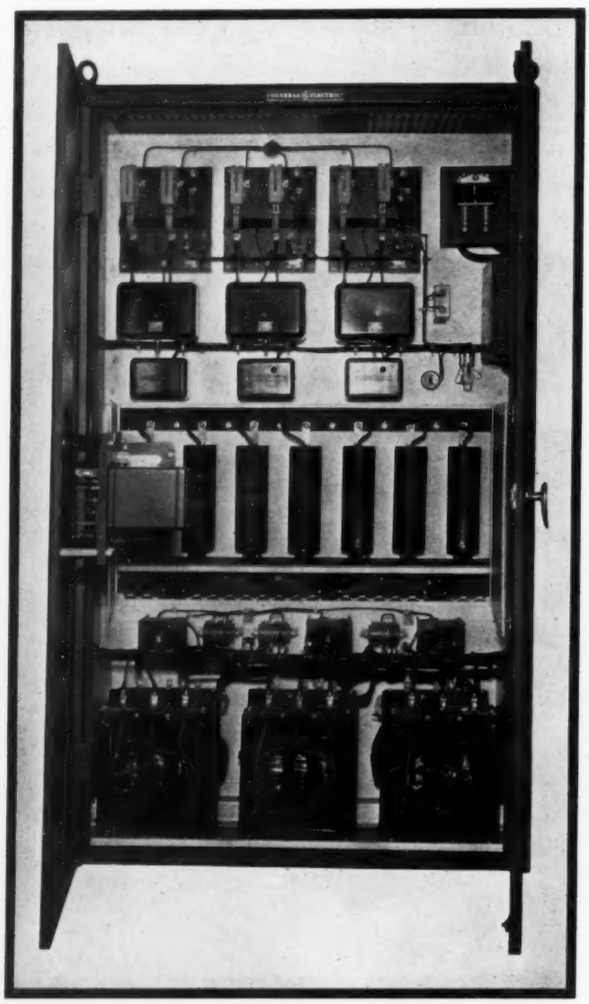
POWER RECTIFIERS, ETC.

An important part of the field for power tube application involves rectifiers and converters at the 250- and 600-volt levels. Here lack of vibration, low weight, efficiency space requirements, and the possibility of low cost automatic operation favor tubes and justify the use of electron devices in many cases.

One successful medium power application in this field is that of rectifiers used to supply elevator power. See Figure 5. Here the size and type of load is entirely suitable for the hot-cathode tubes. Seven 25- to 50-kw equipments have been in service about two years.

Several large power rectifiers and converters are in service with the hot-cathode tubes. For the most part they are operating well and individual tube life in excess of 20,000 hours is being obtained. But the basic cost of these designs precludes any general use. A rectifier of more recent design placed in service last year using metal pool tubes shows a material reduction in the dollar per kilowatt hour figure.

FIGURE 4—Application of rectifiers used to supply elevator power.



SPECIAL REQUIREMENT APPLICATIONS

Occasionally special requirements dictate tube equipments. An example of special requirement is the need for wide range and rapid response excitation systems for synchronous condensers. Vacuum tube regulators have been built and operated on exciter fields successfully for many years. However, full advantage of the high-speed action could not be taken due to the lag introduced by the exciter itself. Over four years ago the first combination tube regulator and power tube exciter was placed in service on a 15,000 kva rotating condenser. This used hot-cathode tubes and average lives of over 20,000 hours are being obtained. Last year an improved equipment for a 30,000-kva condenser was placed in service using the more economical pool type of tube.

Various forms of speed control comprise another type of special requirement application. The thyratron motor is an example. Here a synchronous motor is given a series motor characteristic by the addition of a tube unit. An installation of this nature for speed control of a boiler fan has been in service for about two years.

Another example is speed control for wire and cable-reeling motors automatically to maintain constant tension with varying drum diameter.

A great deal of advance work on tubes and circuits is also being carried out. D-c transmission of electric power is an instance of this work, and a 4500-kw equipment is in regular operation over a 20-mile line.

POWER TUBE APPLICATION PROBLEM

There has been a tendency to expect a very rapid increase in the use of tubes for industrial and power purposes. This is natural in view of the mushroom growth of the radio tube industry. There, an entirely new business was created and tubes at both the transmitter and receiving ends were the only suitable way to accomplish the result. Cost was seldom an important factor until recently.

Most tube engineers realize that a different situation exists in applying tubes industrially. Most things can be accomplished by present methods and equipment. This equipment is the result of many years of intensive development, resulting in rock bottom costs and a high degree of dependability. In other words, it is well entrenched.

To meet this challenge, tube engineers must be able to do things better, or at lower cost, than existing methods, and there are many places where even at this time it is possible to do this. A number of examples have already been given. With the applications, where tubes can stand on their own merits as a start, we should be able to reduce costs and eventually to compete directly with rotating machines. In any case, it is felt that power tubes have a definite and legitimate place in industry and that the next few years should mark the rapid extension of power tube application.

COPPER *Oxide* RECTIFIERS

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EAST PITTSBURGH, PA.

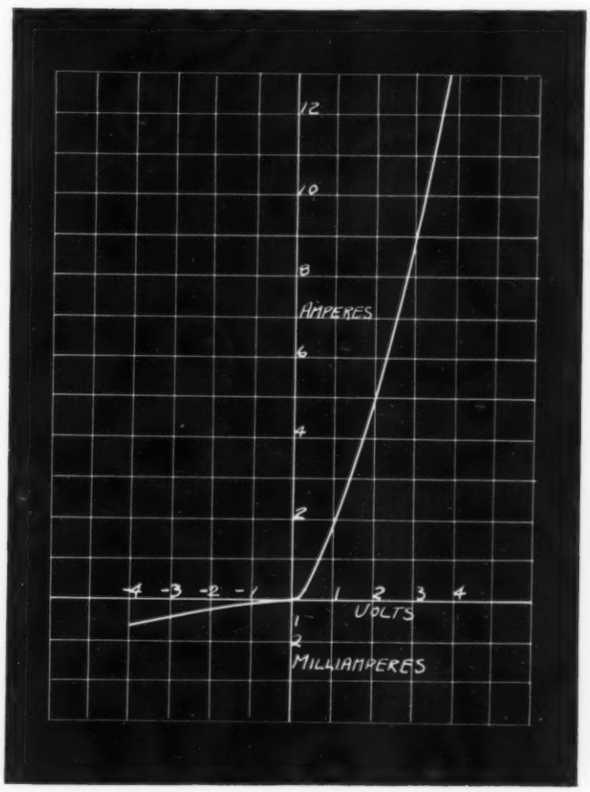
Presented before the A. I. & S. E. Philadelphia Section, Saturday, November 6, 1937

▲ ABOUT sixteen years ago, the copper oxide rectifier was discovered. (1) Since that time, considerable has been learned as to the unusual characteristics of the device and great progress has been made in its application to industrial and other uses. It is the intention here to make clear, without going too far into detail, what this rectifier is, how it works, and where it can best be used.

CONSTRUCTION AND CHARACTERISTICS

The elementary form of the copper oxide rectifier consists of a disc or plate of copper, which has been oxidized on one or both sides in a proper manner. In the process of making this unit, a coat of red or cuprous oxide forms first next to the copper, while a coat of black or cupric oxide forms on top of the red oxide. The black oxide, being highly resistant, is removed, so that the final product consists only of copper and cuprous oxide.

FIGURE 1—Volt ampere characteristic of single 1½" diameter copper oxide disc.



This unit of copper and cuprous oxide which is called the copper oxide disc, has some remarkable properties. If a voltage is applied across a 1½" diameter disc in the low resistance direction, for example 3 volts, the resistance will be quite low and a current of the order of 9 amperes will flow. If then the polarity of the voltage is reversed, the resistance will increase many thousand times and the current flow will be reduced to about 1 milliampere. The ratio of the two resistances then at that voltage would actually be 9000/1. This disc then is evidently quite a good rectifier with the very desirable properties of being entirely metallic, completely dry, and with no moving parts.

Assembly of the original rectifier was accomplished by punching a hole in the center of the rectifier discs and then stacking the discs on an insulated bolt. It was found necessary because of the high contact resistance of the cuprous oxide to graphitize the outer surface and then to place a soft lead washer between the oxide and the next member. The entire stack was then clamped together under high pressure. This gave a workable rectifier assembly and one that has endured with practically no change from the beginning until now.

DETERMINATION OF RATINGS

At the very beginning, considerable study went into the matter of determining suitable ratings for these disc assemblies. Primarily, ratings are based on the fact that the copper oxide rectifier acts as a resistance device in either direction. Units placed in series then will divide the voltage in either direction in proportion to their resistance. Units in parallel will split up the load inversely as their forward resistance. So to begin with, it can be said that if reasonable care is taken to prevent large differences in unit resistances, units may be placed in series or in parallel to any desirable extent.

The next point of importance is that temperature

(1) "The Copper-Cuprous Oxide Rectifier and Photoelectric Cell", by Dr. L. O. Grondahl, Review of Modern Physics, Volume 5 (April, 1933) No. 2, Page 141. (Also includes bibliography up to that time.)

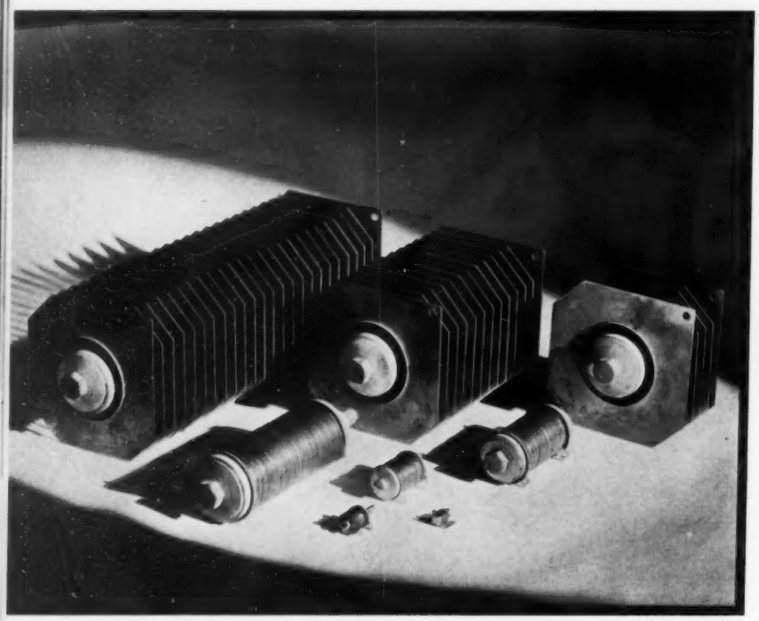


FIGURE 2—Group of typical copper oxide disc type rectifying units.

was found to play an important part. It was discovered that if rectifiers were kept cool, they had greater stability, could carry more load, and showed less change in characteristics with time. So cooling fins were introduced very early in the rectifier development. Most of the units built today will be found to have cooling fins to aid in dissipating heat.

The heating of the rectifier was naturally due to the I^2R losses developed in the forward direction by the load current and in the back direction by the leakage current. It is interesting to consider these separately. (5)

Since the resistance in the forward direction decreases with increasing temperature of the rectifier, the forward losses must decrease with increasing temperature.

Also since the back resistance decreases with increasing temperature, the back current with constant a-c. voltage applied must increase, and consequently the back losses must increase as the temperature rises.

The total losses then will be the sum of the forward and back losses.

A more general view of the matter can be obtained from the comparison shown in Figure 3, which shows the total loss curves of three different rectifiers, all delivering the same output. Curve B is for a rectifier working at a high current and low voltage per disc, Curve A for a rectifier working at a high voltage and low current per disc, while Curve C is for a rectifier working at medium values of both current and voltage. Obviously, a rectifier with the characteristics of A would be unsafe, since its losses increase rapidly with temperature and show a runaway tendency. All things considered, Curve C is felt to be the ideal selection, having practically constant losses over the usual operating range of temperature and also far better efficiency over all than either of the other characteristics. Most rectifiers are rated so as to have this type of loss curve.

So much has been said about keeping these rectifiers cool, it is natural to ask, "Why not use a fan?" The answer is that fans are used on these rectifiers in many applications. The result has been to reduce the size and cost of the rectifier and enable it to reach into wider fields of application. The disadvantage, of course, is the introduction of moving parts into a rectifier that otherwise has none. Fans and blowers, however, are so reliable that they do not actually add much hazard to operation.

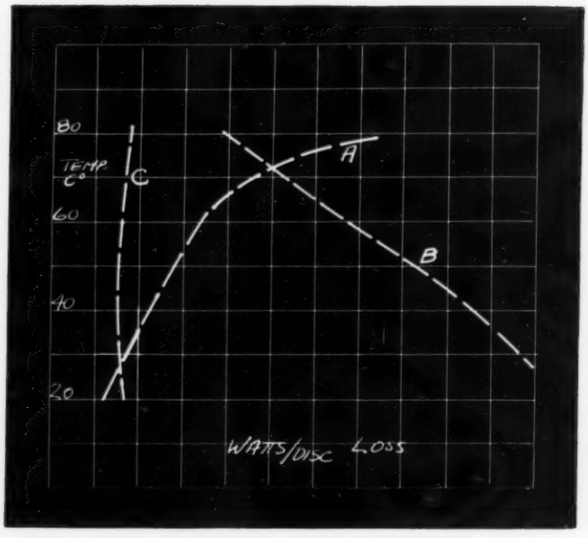
PLATE CONSTRUCTION

The introduction of forced draft increased the range of application but not as much as was desired. There were still hundreds or thousands of small elements in any rectifier of appreciable capacity, say 2 or 3 kw., and above that too many even to consider. The natural direction in which to move, of course, was toward an element of large area than the long standard 1½″ diameter disc. The problem was difficult mainly on account of the high pressure used in the disc assembly, and the requirement that the pressure be uniformly applied to all parts of the disc surface. This was solved by the development of an element that no longer required pressure, thus permitting the size to be increased almost without limit. The result of this was the relarively new plate type copper oxide rectifier. (2)

The copper is now oxidized on both sides. The pressure problem is solved, or rather eliminated, by applying a sprayed metal coat to both sides of the plate. This permits current collection to be made by means of spring clip connectors, which also parallel both sides of the plate.

Two sizes of plates are made at present, 10″ long, one 3″ and the other over 4″ wide, equivalent to 40 and 65 of the 1½″ discs respectively.

FIGURE 3—The total loss curves of three different rectifiers, all delivering the same output.



The plate assembly is readily made by placing a number of plates on studs, either in series, or in parallel, or both as needed. The structure is ideally suited to forced cooling, the cooling air passing between the plates and thus being in intimate contact with every square inch of rectifying surface.

A unit assembly consists of one or more rows of plates, built up in convenient sizes, the maximum being determined by considerations of weight, ease of assembly, as well as by the capacity of the available cooling fan. In Figure 5, for example, is a small unit having only thirty plates, which are connected three phase to deliver about 2 kw. on an intermittent basis. Figure 6 shows a unit of 3 kw. continuous capacity, or 500 amperes at 6 volts d-c. This is the type of unit which was developed primarily for electro-plating service.

APPLICATIONS

So much briefly for characteristics and construction. Applications of the rectifier to industrial uses have been going on for ten years. This process proceeded quite slowly at first, as users were properly cautious about such a new and unproved device. Today, it is correct to say that the question of proving the rectifier is no longer an item. Dependability has been established and now it is simply a question of fitting the proper rectifier to the particular job.

Perhaps the best procedure will be to review a few of the more prominent applications, pointing out those features that make the rectifier suitable for each job.

1. *Battery Charging.* Among rectifying applications, battery charging is of course a leader. Everybody has batteries for some purpose and they must be charged. Battery charging generally is of two types, cycle charging, in which the battery is brought back from discharge to full charge in a short time by charging

FIGURE 4—Cross-sectional view of plate type copper oxide rectifier.

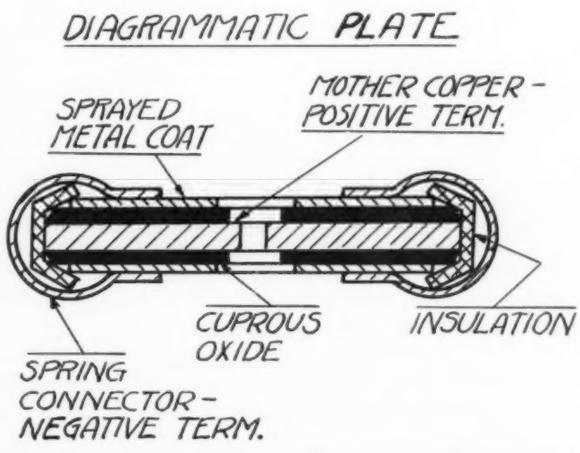


FIGURE 5—Plate type rectifying unit assembly for two kilowatt intermittent service.

at a high rate, and floating or trickle charging, in which by means of a continuous charge at a low rate, the battery is always kept in the proper state of charge. While the copper oxide rectifier, being a rectifier, can of course be used for any type of charging, it is by nature best suited to the floating charge, particularly in unattended locations. Long life, freedom from radio interference, ease of adjustment of charging rate, absence of parts needing replacement or maintenance speak well for the rectifier in this service.

For deluxe floating service, a charger has been developed known as the Rectomatic, which will hold the battery voltage within close limits automatically. The charger itself varies the rate of charge by magnetic means according to the needs of the battery.

2. *Control.* In the field of control, one would expect to find many copper oxide units, and such applications have been widespread. The advantages which d-c. control has in many cases are well known to everyone. With a-c. supply practically universal, the existence of a rectifier that is a static noiseless piece of equipment requiring no attention or maintenance has been the solution of many difficult problems. For example, in many small elevator systems, d-c. control and brakes are desired because of their smooth, quiet

(2) "The Rectox Rectifier Grows", by I. R. Smith, Electric Journal (May, 1937).
(3) "Electrical Pipe Line Drainage", by G. I. Rhodes, Electric Journal (February, 1936) Page 91.
(4) "Rectifier—Floating—Battery Supply for Fire Alarm Systems", by F. R. Bridges, Fire Engineering, (December 23, 1931).
(5) "Copper Oxide Rectifiers for Motion Picture Arc Supply", by I. R. Smith, Journal of the Society of Motion Picture Engineers, (September, 1936) No. 3, Page 331.
(6) "Application of the Copper Oxide Rectifier to Motion Picture Projection", by C. E. Hamann, Journal of the Society of Motion Picture Engineers, (September, 1936) No. 3, Page 341.

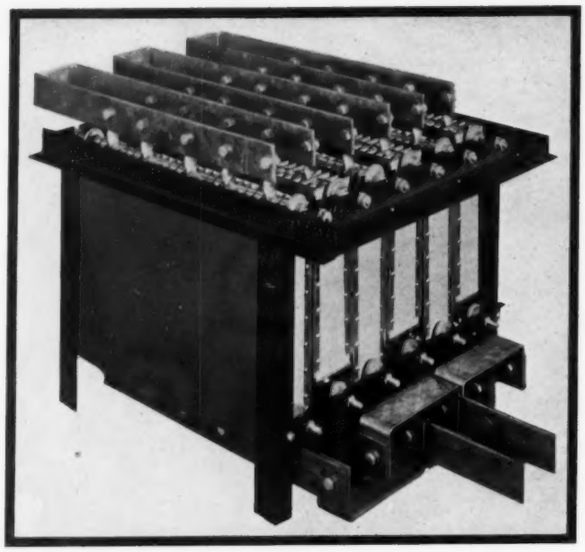


FIGURE 6—Plate type unit assembly for three kilowatt continuous output.

operation. Rectox units have been designed for this service which operate standard 220 volt, d-c. control directly from 230 volt, 3 phase a-c. supply without a transformer. Thousands of such units are in regular service now all over the country.

3. *Electrolysis Mitigation.* Electrolysis of pipe lines and other underground structures has always been a source of a large amount of field trouble involving great expense. (3) Studies in the field over many years have proven that localized electrolytic action which has been responsible for corrosion and failure of pipe lines all over the country can be stopped apparently completely if the pipe can be maintained at a slight d-c. potential below the surrounding earth. Since the amounts of d-c. power required in general are not large, and the voltages are low, the copper oxide rectifier was found to be the most efficient source of d-c. for this purpose. Such rectifiers may be mounted on poles outdoors along the right of way at proper intervals. Once installed and adjusted, the need for maintenance or attention is practically over. Other installations are made indoors.

4. *Circuit Breaker Operation.* It was early found that the copper oxide rectifier possessed a large overload capacity so that if only a short time operation were needed, many times the normal rating of the unit could be delivered with entire safety. It was also found that the operation of the rectifier was instantaneous. As soon as voltage was applied, current began to flow.

Both of these characteristics led directly to the use of these rectifiers for closing solenoid operated circuit breakers. Since the closing operation lasts for less than a second, the usual ratings of the discs are increased a hundred times or more. Units with capacities of from 6 amperes to 250 amperes at 125 volts d-c. have been in regular use for years on power systems and in industrial installations all over the country.

5. *Fire Alarm System.* Reliability and dependability of the copper oxide rectifier are best illustrated by its application to the fire alarm telegraph systems of the country. In former days, such systems were entirely battery operated. Each box circuit had two batteries, one of which was charged while the other energized the box circuit. Today in most installations, one of the batteries has been replaced by a copper oxide rectifier which supplies the load and at the same time keeps the single battery in condition to supply standby power if needed. (4) In the New England District alone, 93 per cent of the municipal fire alarm systems today are of this type.

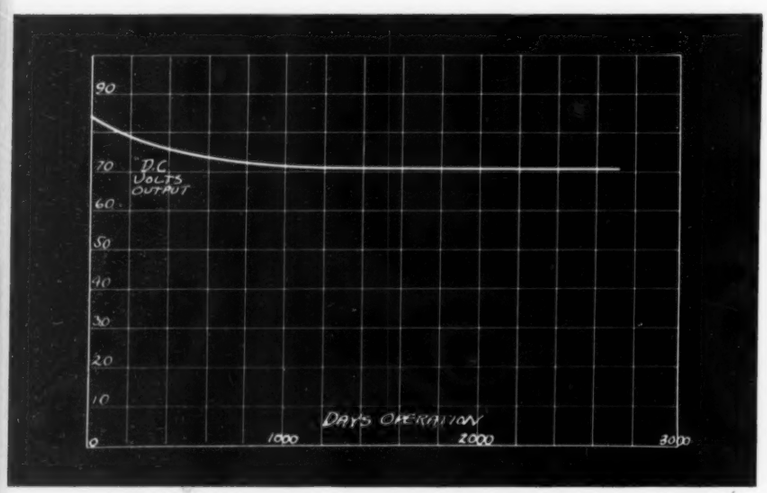
6. *Business Machines.* Business machines constitute a large class of equipment found in some form or other in every manufacturing plant. Time clock systems, time stamps, door locks, key punches, Teleautographs, Auto-calls, all require a d-c. source. Today time clocks generally use the copper oxide rectifier as a source of the d-c. impulse which moves the clock ahead each minute. Many other applications have been made in this field.

7. *Communication.* Communication systems occur to one as being large users of d-c. Many battery eliminators are made now with rectifiers supplying talking and ringing currents through a suitable filter system delivering d-c. that is practically as smooth as that furnished by the battery. The largest user of communication rectifiers has been the Bell Telephone System where they will be found in all types of low voltage battery charging work, operating communicating systems, sending teletypes, or in the form of valves in many kinds of relay circuits.

8. *Arc Projection.* Forced cooling was first applied to rectifiers that were furnished to the motion picture industry for operation of projection arc. (5, 6) Such rectifiers deliver approximately 2 kw. to projection arcs of the high intensity Suprex type.

9. *Electro-plating.* Perhaps the most promising as well as one of the newer applications of the rectifier has been in the electro-plating, or rather in the electro-chemical industry. (2) This extension of the field of the rectifier was made possible by the development

FIGURE 7—Life test curve showing variation of output with time, average for ten units for operated in laboratory test on electro-magnetic type load.



of the large capacity plate unit. The advantages of the rectifier for this service are of course the elimination of all rotating parts with the exception of the ventilating fan, elimination of brushes and brush maintenance, of the need for special heavy foundation. Efficiencies slightly below those of motor generator sets can be obtained. The first such unit built was a 500 ampere, 6 volt rectifier, completely self-contained with fan, meters, and control.

A still larger rectifier was then built rated at 2000 amperes and 6 volts. This was split up for greater ease of handling into rectifier cabinets, each 1000 amperes, 6 volts, and one transformer and control cabinet. All three cabinets are fan cooled and again the installation is complete with meters, control, transformers, and rectifiers.

Of all the characteristics of the rectifier, the most important is that of long life. Many rectifiers have been operated on life test in the laboratory for many years. The results of a typical test may be of interest. Figure 7 shows an average curve of units operating on electro-magnetic load and brings out quite well the effect of time on the output of rectifier. It will be noticed that while there has been a reduction in output with time, there has been practically no reduction for over half of the total life of the rectifier. This test, it will be noticed, has extended continuously for nearly 2700 days of operation.

In the eyes of many people, the copper oxide rectifier has been felt to be a mysterious, unpredictable piece of equipment. That this is not a true picture, but that the performance is entirely predictable is evidenced by the wide variety of applications in which it is used and of which only a few have been described above. Greater familiarity with its characteristics, advantages, and disadvantages will undoubtedly result in a gradual widening of its field of application in all types of industry.

DISCUSSION

PRESENTED BY

F. O. SCHNURE, Electrical Superintendent, Bethlehem Steel Company, Sparrows Point, Maryland.
L. V. BLACK, Assistant Electrical Superintendent, Bethlehem Steel Company, Bethlehem, Pennsylvania.
L. F. COFFIN, Mechanical Superintendent, Bethlehem Steel Company, Sparrows Point, Maryland.
H. H. ANGEL, Electrical Engineer, Bethlehem Steel Company, Sparrows Point, Maryland.
E. J. NOPPER, Electrical Engineer, Sun Oil Company, Philadelphia, Pennsylvania.
H. E. HOUCK, Engineer, Du Pont de Nemours & Company, Wilmington, Delaware.
J. C. REED, Electrical Engineer, Bethlehem Steel Company, Steelton, Pennsylvania.
W. E. GUTZWILLER, Electrical Department, Rectifier Division, Allis-Chalmers Manufacturing Company, Milwaukee, Wisconsin.
O. W. PIKE, Vacuum Tube Engineering Department, General Electric Company, Schenectady, New York.
I. R. SMITH, Section Engineer, Control Engineering Department, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pennsylvania.

F. O. SCHNURE: Mr. Chairman, members of the Association of Iron and Steel Engineers: I am sure that we all agree the papers tonight have been very educational, particularly to those of us who have been anxious to find out where we could apply any of the three types of rectifiers described.

The mercury arc rectifier will come into general use in steel mill service when its reliability has been amply demonstrated. Its application would be accelerated if and when it can be applied to the non-reversing type of d-c. load common to continuous strip mills. I understand development along this line is under way.

On power tubes I would like to inquire what capacities are available for industrial use. I notice one of the illustrations covered a 1,000 ampere, 900 volt tube. We are really not interested in 900 volts; we are reasonably interested in 600 but more particularly in 250 volt installation.

On copper oxide rectifier I would like to inquire if its voltage characteristics are smooth enough to operate tele-typewriters from 25 cycle circuits.

In concluding I want to thank all of the authors for coming to us with these excellent papers.

L. V. BLACK: I have looked forward for quite some time to attending this meeting to hear these papers delivered and I feel I have been amply repaid for the effort.

I have several questions I'd like to ask regarding Mr. Gutzwiller's paper. I wonder how the rectifier will divide the load in parallel with motor generator sets. In his paper he mentioned that there was provision for operating the rectifier at a future time in parallel with either motor generator sets or a rotary converter. The question in my mind is how the rectifier would divide the load.

Another question: What is the range of vacuum under which the rectifier operates? How many inches of vacuum is maintained?

Another question: Will the rectifiers operate equally successful on 25 cycle and 60 cycle power?

Discussing Mr. Pike's paper: What will be the effect of high overloads on the tubes? If high overload is subjected to the tubes is it damaging? If so, what overload protection is applied?

For the copper oxide rectifier I would like to ask Mr. Smith if copper oxide rectifiers are installed in an atmosphere which is dirty or gaseous must the

copper oxide rectifier be provided with a dust-tight compartment or some other means of protection?

L. F. COFFIN: I would like to ask whether the relation between a-c and d-c voltage on the copper oxide rectifiers holds at one to one in all cases.

H. H. ANGEL: Mr. Chairman, it is needless to say I have certainly enjoyed these papers very very much tonight. I have one general question to ask which applies to all three types of rectifiers; it is rather similar to Mr. Black's question. What is the effect on the various rectifiers under heavy short circuits? For example, when we have heavy shorts on the d-c. end of motor generator sets or rotary converters, they make themselves evident by arcing or flashovers. Now, then, have tests been made on the mercury arc rectifier which indicate what is the destructive effect with very heavy shorts and also what is the effect on moderate shorts if the breaker which Mr. Gutzwiller mentions is a little bit slow in opening the circuit?

In Mr. Smith's paper on the copper oxide rectifiers, I'd like to know what is the effect also on short circuits of contactor coils which are placed across these rectifiers because I have had some experience with a few rectifiers failing and I have never learned just what has been the cause of that failure; whether it has been shorts in the closed circuit or some other cause such as gas.

E. J. NOPPER: I have enjoyed the meeting very much on all three types of rectifiers.

The copper oxide rectifier is the type of particular concern to us as it finds application in connection with circuit breakers. I would like to ask whether or not the very heavy closing current of the solenoid operated type breaker will have any serious effect on the rectifier, and, just what life might be expected in this service.

Also, what happens or what are the manifestations of rectifier failure. Would there be an arcing of any consequence across the plates, or would it be merely a pinpoint spark? When this type of rectifier does fail does it become a conductor during both halves of the cycle or would it become, in effect, an insulator?

H. E. HOUCK: I have no questions, I think, but I do want to take advantage of this opportunity to congratulate this Association on the standing which it has attained in the steel industry. I regret sometimes that we electrical engineers in the chemical industry don't have a similar organization and we thank you very heartily for the opportunity we have occasionally to drop in on your meetings when you have papers of particular interest to us. Thank you again.

J. C. REED: I might state that we have used the copper-oxide film type of rectifier for a number of purposes, such as, the operation of time clocks, mill controls and fire alarms, with satisfactory results. There are a few questions I wish to ask: First—The direct current being more or less of a pulsating nature; will these pulsations be detrimental in the operation of a lifting magnet? Second—Will the use of 25-cycle current as a source of supply have any advantages or disadvantages over the use of 60 cycles?

I have another question to ask Mr. Gutzwiller: As I understand the operation of the mercury arc rectifier, the efficiency of conversion increases with the d-c. voltage output. Why then, if you make the d-c. voltage high enough, cannot a very efficient frequency changer be made?

1. WARD-LEONARD CONTROL WITH MERCURY ARC RECTIFIER

W. E. GUTZWILLER: Ward-Leonard control of a d-c. motor using a rectifier instead of the conventional motor-generator has already been used in a number of commercial installations. This control has been made possible by the development of control grids. By properly controlling the arc in the rectifier it is possible not only to change alternating current into direct current at variable voltage, but also to invert direct current back into alternating current. Due to the valve action of the rectifier it is, however, necessary, when changing from rectification to inversion, to keep the current flowing in the same direction. In order to reverse the flow of energy it is therefore necessary to reverse the voltage. This can be accomplished by the grid control in such a way that current is forced through the rectifier from the d-c. source at the time the anodes receive negative a-c. potential from the rectifier transformer.

This method of power reversal is the opposite of the conventional method where rotating machinery is used for conversion.

In order to obtain a smooth changeover from forward to reverse power, or vice versa, equivalent to the reversal of the field of the Ward-Leonard generator, it is desirable to provide two rectifier tanks connected in parallel on the d-c. side with reversed polarity. The two tanks can be connected to a common transformer. With the proper grid control the rectifier tanks can be operated so that one tank will furnish the power for forward operation of the d-c. motor, and the other for reverse operation. No change-over switching equipment is thus necessary in the leads to the motor.

The necessity of providing two rectifiers somewhat increases the first cost of this equipment, and therefore makes rectifiers for Ward-Leonard control economical only in larger capacities and for higher d-c. voltages. A number of commercial installations employ rectification and inversion in connection with electric railroads, where the inversion feature is uesd for regenerative braking of the locomotives. There have also been installed a number of rectifier-inverted units supplying mine hoists, where the rectifier has to take care of the reversing of the hoist motor as well as of regenerative braking.

2. OVER-ALL EFFICIENCY OF REPUBLIC STEEL RECTIFIER

The overall conversion efficiency of the rectifier unit described in this paper, at partial loads and including the losses in the rectifier, in the transformer, and in all the auxiliaries, is estimated as follows:

88 per cent efficiency at 25 per cent load
89 per cent efficiency at 50 per cent load
89 per cent efficiency at 75 per cent load

3. PARALLEL OPERATION OF RECTIFIERS WITH MOTOR GENERATORS

In order to obtain an equal load division between a rectifier and a motor-generator, it is essential that the two machines to be paralleled have substantially the same inherent voltage characteristic. The inherent voltage characteristic of the rectifier is drooping, with some 6 to 7 per cent voltage drop from no-load to full load. The voltage drop in the rectifier is mainly due to the transformer reactance.

As far as the effect of a-c. voltage variations on the rectifier d-c. voltage is concerned, this is similar to that on rotary converters, i. e., the d-c. voltage varies approximately in proportion to the variations in the a-c. supply voltage. In installations where the a-c. supply voltage varies a great deal. and also where rectifiers have to be paralleled with flat or over-compounded rotating machinery, it is necessary to modify the inherent voltage regulation. This can be accomplished relatively easy by the use of automatic grid control devices, such as are installed in connection with the rectifier described in this paper. These grid control devices are made responsive to load unbalance and act in a manner similar to the equalizers used with compounded d-c. generators.

4. EFFECT OF SYSTEM FREQUENCY ON OPERATION OF RECTIFIERS

The operation of the rectifier is not materially affected by the frequency of the primary supply system. Where, for instance, two cources of power of different frequencies are available at the substation, the rectifier transformer and the auxiliaries can be designed for operation on both frequencies, whereby greater flexibility of substation operation is obtained. Many rectifier substations have been built to operate on 25 and 60-cycle power supplies. Some of them are unattended stations and the changeover from one to the other frequency can be carried out automatically or by supervisory control upon the failure of one of the supply systems.

5. SHORT-CIRCUIT CAPACITY OF RECTIFIERS

The rectifier is capable of withstanding repeated d-c. short-circuits without being harmed, provided the short is disconnected in a reasonable time. This desirable characteristic, which is due to the absence of brushes, commutators, synchronous forces, etc., has been mainly responsible for the success of the rectifier in the field of electric traction, where heavy d-c. short-circuits are of relatively frequent occurence.

If the d-c. short is not disconnected in a reasonable time, the rectifier anodes may become pitted, and arc shields and control grids may be distorted or burned. In the few cases known, where rectifiers have been damaged due to failure of the switchgear to clear a fault, the unit could be repaired at relatively little cost as compared with the repair cost of damaged commutators, brushes, brush gear, and armature windings of rotating machinery.

6. EFFECT OF D-C. RIPPLE ON LOAD

The major pulsation or ripple in the d-c. voltage of a 6-phase rectifier, which is due to the successive firing of the anodes, is approximately 6 per cent of the d-c. voltage and of a frequency equal to six times the frequency of the a-c. supply. For a 12-phase rectifier the major voltage ripple is approximately 2½ per cent of the d-c. voltage and of twelve times the frequency of the a-c. supply. The higher the number of rectifier phases, the lower is the ripple voltage, but the higher is the frequency of the ripple. A reduction of the rectifier voltage by grid control increases the ripple voltage.

The relatively high reactance of motor and lifting magnet windings at the ripple frequency prevents the flow of any appreciable amount of ripple current. Measurements show that the ripple currents with motor and lifting magnet loads are of the order of 1 per cent or less of the load current.

With close to 700,000 kw of rectifiers installed in this country today, no difficulties have been encountered with commutation or overheating of motors and magnet windings, due to the rectifier ripple voltage.

7. VACUUM IN RECTIFIER

For satisfactory operation of the rectifier a vacuum of from 1 to 15 microns has to be maintained. This vacuum is automatically held by vacuum pumps and an electric contact-making vacuum measuring device. The vacuum is expressed in microns. One micron is 1/760,000 of atmospheric pressure at sea level.

8. OVERLOAD CAPACITY OF RECTIFIERS

A rectifier with a continuous rating can be overloaded for short intervals where an emergency exists, such as, for instance, the loss of another converting unit. Some cases are known where in electrolytic plants rectifiers were operated for hours at from 10 to 25 per cent overload, to take care of an emergency situation, and without apparently showing any signs of distress. As in any other type of electrical machinery, the overloading of a rectifier develops hot spots. In a rectifier these hot spots develop on vital parts, such as anodes, grids, arc shields, etc., causing undue deformation of these parts, and resulting in evaporation of material. The vapors thus produced condense on the inside parts of the rectifier and gradually lower the dielectric strength of the electrode insulation, thus causing a rapid increase in backfires. Repeated overloading will shorten the life and will require frequent and costly overhauling of the rectifier. It is difficult to make a guess as to how often a rectifier can carry moderate overloads. The frequency of over-haulings and their cost will depend on the severity of the overloads and the time during which they have been carried. It is possible that a rectifier which under normal operating conditions may require an overhauling every ten years, may require overhauling already after five years due to the effects of occasional overloads. One case is known where a rectifier in an electrolytic plant required some repairs after one year's service during which it carried, due

to an error in metering equipment, approximately 25 per cent overload for several weeks.

9. RECTIFIER FREQUENCY CHANGERS

Frequency changing can be accomplished by changing alternating current of a given frequency to direct current with one rectifier, and inverting the direct current back to alternating current of another frequency by a second rectifier. There are a number of commercial installations on railway systems where rectifier-inverters serve the following three-fold purpose. They first convert alternating current power into 3000-volt direct current power; second, they invert energy regenerated by the locomotives back into alternating current of either one of two frequencies, and third, they tie two alternating current systems of different frequencies together through a 3000-volt direct current bus.

Three-phase single-phase rectifier frequency changers in one tank have also been built supplying single phase a-c. power to a railway system of low frequency from a 3-phase, 50-cycle power system.

H. E. Houck: We all know in the case of rotating machinery or static machinery such as transformers the rating of the machine is determined largely by its ability to dissipate heat. That is true in those cases where cotton and similar materials are used for insulation. I'd like to ask Mr. Gutzwiller what would be the nature of the fault which might be expected on a metal tank rectifier if operated at overloads of the order of 25 per cent or 30 percent over a sustained period. In other words, in what manner would that fault make itself apparent in the machine itself.

O. W. Pike: With respect to the question on capacity of tubes, the particular slide shown illustrated a welding type of tube having a peak voltage rating of 900 amperes. This is sufficient for the voltages commonly accounted in welding service. Tubes of essentially that same type can be made to stand sufficient peak voltage for 600-volt rectifier operation, which is around two thousand volts, and the same tubes are satisfactory for 250 volts. At the present time we are building individual tubes having ratings of 100 and 250 amperes average current. These are of the half-wave type and can be used in groups of four, six, or possibly eight in a given rectifier. With eight tubes of the 250-ampere size, a rating of 2,000 amperes direct current is possible while four 100-ampere tubes would give 400 amperes. These illustrate the maximum and minimum size of polyphase rectifiers possible with those two power tubes.

Regarding short circuits, I will limit my discussion to sealed-off tubes as the pumped rectifiers have been covered. Overloads are a limitation of the hot-cathode type of tube. Hot-cathode tubes require either high regulation transformers or fast breakers, but if these circuit conditions are met, they are entirely satisfactory for most purposes. In fact, we have ample evidence that hot-cathode tubes actually improve under mild short circuits. In the radio transmitter rectifier field when a short caused by a transmitter tube failing throws a rectifier off for a few cycles, the rectifier can often be put back on immediately with no trouble. However, in the pool type tube we have a much greater ability to withstand overloads and short circuits and in this respect it is comparable to the pool cathode tanks. An interesting point not usually realized is that with both the hot cathode and the pool type of sealed-off unit we have a form of internal pump. In the case of the hot-cathode tube the cathode itself acts as a chemical pump, cleaning up gas. In the case of the pool type tube gas is also cleaned up under operation. Thus, if a short circuit releases some gas in the sealed-off tube it is usually cleaned up by subsequent operation. However, heavy short circuits can damage tubes and a reasonable amount of protection is necessary in all cases.

The question regarding the effect of ripple has been answered. An interesting point I might bring out about ripple refers to radio transmitting rectifiers. These usually have six-phase smoothing and are followed by a filter. This filter is not nearly as good for smoothing as many industrial devices supplied from rectifiers, yet a radio transmitter is a very sensitive device from the standpoint of ripple.

I. R. Smith: The first question was as to the use of a copper oxide rectifier on telephone circuits without batteries, particularly for operating teletype printers. The single phase rectifier delivers a pulsating wave which varies from zero to its maximum value twice each cycle. Such a d-c. wave would not be satisfactory for use on telephone circuits or for operating teletype printers. In either case, it is necessary to reduce the amount of a-c. ripple in the output wave of the rectifier to whatever value has been found by experience to be necessary. Reduction of the ripple voltage to satisfactory values in practice is accomplished by inserting a conventional type of filter in the output circuit of the rectifiers. By means of such filters the output wave of a single phase rectifier can be smoothed out until it is practically equivalent to a storage battery. Operation of a teletype printer does not require filtering to this extent, a reduction in the ripple voltage to about 3 per cent of the total output voltage being all that is required. Several thousand such filtered copper oxide rectifiers are in service today, operating teletype printers.

2. The next question was as to the life of the rectifying film. How long will it last and when will it fail? That is a question that really can't be answered as yet. So far as is known today, there is no limit to the life of the rectifying film in the copper oxide rectifier. Life tests in our own laboratories have operated about eleven years and in general the type of operation is similar to what was shown; from such a curve no one can really tell if there is to be a definite termination in the life of the rectifier, but all indications are that this will not be the case. As shown in that curve, there was a reduction in output at the beginning, which was due to a change in the characteristics of the rectifier, this change sometimes being known as "aging". The effect of aging is to increase the resistance of the rectifier in the forward or useful direction, with time, the amount of increase depending on the operating temperature of the rectifier. That increase in resistance, then, considering the rectifying

unit as part of a complete circuit which includes the impedance of the load, the supply transformer, and any other parts of the circuit, is naturally most noticeable at the beginning of operation. As time goes on, the changes in the rectifier resistance become less and less and they become a smaller and smaller part of the total circuit resistance and have practically no effect on the output of the rectifier.

3. The third question related to the operation of the copper oxide rectifier in dusty or gaseous atmospheres. The rectifier without proper protection cannot safely be operated in gaseous or overly humid atmospheres. However, it has been standard practice for some years to provide the rectifier with protective coatings consisting of one or more coats of a good insulating varnish. In extra severe conditions, such as are found in oil refineries, it is possible to go a step further and completely enclose the rectifying discs by some material such as cork. Under these conditions, the operation is entirely satisfactory.

Plate rectifiers at the present time must be operated in atmospheres that are free from corrosive elements. No precautions, however, are taken to keep out dust and we do not believe it will be necessary to take any except in extreme cases.

4. The relation between a-c. and d-c. voltages in a single phase, full wave, copper oxide rectifier is probably best understood if one considers that this rectifier acts really as a series resistance between the applied a-c. voltage and the d-c. load. Thus, the only difference between the a-c. and the d-c. voltages should be the difference due to the resistance drop through the rectifier. However, on single phase operation, d-c. measurements are usually given in average terms, while the a-c. values are expressed in rms. terms. Hence, the relation between the two must take into account the form factor as well as the resistance drop through the rectifier. Generally, the d-c. output voltage at full load for a copper oxide rectifier will be from 70 to 80 per cent of the a-c. input voltage if the load is resistance type.

5. There were two questions on the subject of overloads and short circuits, and their effect on the copper oxide rectifier. Properly rated units have a considerable margin of safety above their normal operating points and hence can withstand heavy overload currents for considerable periods of time without damage. For example, any standard Rectox unit could deliver 100 per cent overload in current for many hours quite safely.

The mechanism of failure is closely tied up with operating temperature. So long as a unit is capable of dissipating its operating losses with a moderate temperature rise there is no danger of failure. But if an overload is placed on the unit of such a value that a considerably higher temperature rise results, and if it should be the case that at this higher temperature the losses in the rectifier had further increased, thus requiring a still greater temperature rise, one can see that the rectifier may become unstable and may fail. While failure, then, in a sense may be the result of excessive temperature, what the excessive temperature may be depends on the unit construction (ability to dissipate heat) and on the unit rating.

Since temperature plays such an important part in the case of a failure, it is obvious that the time element is also important, particularly since the disc type of copper oxide rectifier has large thermal capacity. Hence, overloads that are not applied long enough to raise the temperature of the unit to dangerous values are quite safe. A short circuit then does no harm to a copper oxide rectifier provided it is not maintained long enough to raise the unit temperature to excessive values.

For example, in the copper oxide rectifier used to close circuit breakers, a picture of which was shown, the duration of the load is limited to not more than one second. It has been found by nine years of field service and hundreds or thousands of laboratory operations that on such a duty cycle the usual continuous rating of the rectifying unit can be exceeded by as much as 150 times, with complete safety. Such heavy overloads, limited as they are to very short time, have no effect on the rectifier characteristics.

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PART I - By J. L. WHITTEN

INSTRUMENTATION

Presented before the A. I. & S. E. Annual Spring Conference, Baltimore, Md., April 28 - 29, 1938

By R. H. ELLIS

United Engineering & Foundry Company

PITTSBURGH, PA.

▲ THE procession of continuous strip mills built in America has been extended so rapidly that the association of your speaker with the strip steel industry has been concentrated largely upon it. That continuous mills are becoming an international topic is evidenced by the new construction in Russia, Japan and England. In the latter country it was my privilege recently to aid in equipping the first and second continuous wide strip mills. This experience culminates a long contact with the most interesting instrumentation problem of the steel industry. Invariably an entire plant is involved hence the problems are solved as a completely planned unit with all individual control applications considered in the light of the requirements and standards of the particular plant.

Probably, also, no other steel producing unit ever had the thorough study and consideration given to it that strip mill equipment has, consequently improvements have been developed with every new mill that has made each new unit a most interesting problem and has led to an improvement in the art of instrument design, manufacture and application.

Starting with the installations of the Lackawanna Plant of Bethlehem Steel and the Gary Sheet and Tin Mill, there have followed the installations of the Ford Mill, the Russian Mill at Zaporojie, American Rolling Mill at Middletown, Jones and Laughlin Mill at Pittsburgh, Great Lakes Steel at Detroit, the Republic Mill at Cleveland, Bethlehem at Sparrows Point, the Irvin Mill at Pittsburgh and the new Cuyahoga Works of American Steel and Wire. Although one job has followed on the heels of the other, no two are exactly the same in mill, furnace or instrument design. This is indeed typical of the progress of American Industry in which we can justly take so much pride.

Probably the first several strip mill jobs were not instrumentized as an entirety but each unit at first stood on its own merits. This lack of coordination was not serious and probably was a result of both the steel and instrument companies' lack of understanding of the requirements of the industry. However, subsequent projects were planned from the beginning so that the instrument builders could start with the plant layout and develop the entire instrument equipment as completely as the mills, buildings and handling machinery. Furthermore, this understanding of the industry has helped an appreciation of special problems of control of the various units to the extent that special instruments can be developed by test on existing jobs to meet the new requirements of the next plant. Like any other industry, small details that are so important to the successful operation of the equipment, develop as the studies are made and can be incorporated in the final designs. Continuous pickling control and the specialized controls for radiant type annealing furnaces are particularly good examples of this.

In laying out the instrumentation of a complete mill the first essential is knowledge of furnace design and operation and the combustion requirements of various fuels used in the plant. The combustion engineer on the job is the source of excellent ideas on control which can supplement those of the furnace designer and instrument engineers.

The next essential is the actual plant production layout, or the particular types of furnaces which are to be considered, directly affect the number, type and location of the instruments.

The next essential is a knowledge of all processes of the plant.

One of the important units for which instruments and controls are necessary is the continuous pickler. No less than the best equipment should be installed here.

MODERN STRIP MILLS

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The next essential is a complete knowledge of the instruments and their possibilities in control applications. In other words, strip mill instrumentation has reached the point of being an art and thus compares favorably with the development of this highly specialized industry itself.

The final essential is a knowledge of mill operation as differentiated from that of actual metallurgical or mechanical processing. This consists of learning in what shape the material is handled and just how it moves through the mill. The by-product of this is thermocouple locations, instrument panels, and other units in places where they are most serviceable and accessible for maintenance and adjustment with the least possible loss of time.

With this background now let us consider the requirements of the strip mill.

All the new continuous pickling lines, as illustrated below, have been equipped with potentiometer controls with very satisfying results.

SLAB HEATERS

For controlling the operation of the slab reheating furnaces it has become common practice to regulate automatically the fuel and air to the soaking zone of the furnace. With the idea of treating this zone as a soaking pit, the temperature is measured by a radiation tube or thermocouple placed through the roof to take the temperatures. This temperature impulse, transferred to a recording and controlling potentiometer, of either electric or air-operated type regulates the fuel input to the furnace in accordance with the demands of load variation, full furnace holdovers or shutdown periods. It is particularly important to recognize the load variation in this type of furnace and the automatic control should embody load compensation. Fuel-air rationing equipment and furnace pressure control, of course, will regulate the air supply. While the uniformity of slab heating can be best accomplished by automatic temperature control at the soaking zone, it is not usually thought necessary to regulate the temperature of the heating zones of the furnaces, although some form of multiple temperature should be used to inform the operator of the conditioning of the steel in preparation for soaking. The same equipment is needed for recuperative temperature—waste gas in and out—and preheated air. To protect the exhauster from possible damage from excessive air temperature, temperature control equipment should be installed to adjust a cold air bleeder positioner to insure that the preheated air temperature be held below a value which would be injurious to the fan. Naturally fuel meters should be included in order to measure the consumption of each furnace.

HI-SPEED PYROMETERS

From the slab heating furnaces we naturally go to the hot mill in following the course of the heated metal through its processing. The problem of taking the temperature of fast moving hot bodies is of more recent solution than other forms of pyrometry but instrument and steel manufacturers have devoted much energy to this subject. It can be stated that apparatus that not only measures the temperature of the strip accurately but also reaches a full scale reading on the recorder in 3/5 of 1 second is now available. With speed like this every variation in temperature along the entire length of the strip can be measured as it traverses the roughing and finishing passes and the slab temperature can be obtained end to end as it passes the turn table.

What this information contributes in valuable operating guidance is hardly conceivable until the equipment is observed in operation. From it the heater on the furnaces, roughing rollers, holding table operator and speed mill roller can correlate mill speed with temper-

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ature to achieve rolling results not hitherto possible.

In providing this the following locations should be covered:

1. Temperature of slab as soon after No. 1 scale breaker as possible.
2. Temperature after No. 2 roughing stand.
3. Temperature at holding table.
4. Temperature between the last two roll stands or after the last pass.

The first location mentioned above will enable the furnace operator to reset his furnace temperatures to provide uniform heating on all of the several slab heaters. Quite often furnaces set at the same temperature will not provide uniform heating but the heaters can use the measured slab temperature after No. 1 scale breaker to reset the various control points and equalize the temperature of the metal as it approaches the mill. The temperature after No. 2 roughing stand will be indicative of the amount of drafting on the metal after it has had two roughing passes. Hence it guides the operator in the speed at which the next two roughing stands should be operated in order to provide a slab well elongated and at a temperature which will not require it to be held on the holding table long. Temperature detection at the holding table will verify the operation of the last two roughing stands and will enable the operator of the table to know exactly when to pass the slab into the finishing mills. This same temperature reading transferred to the finishing mill pulpit will enable the operator at that point to set the speed of the mills. With the slab at the proper temperature and the finishing passes started the last check on roll of the material is the temperature at which the metal finishes after it leaves the last pass of the mill. Since this temperature will affect the final metal structure and its requirements on annealing, normalizing and temper passing if for tin plate, it is most important that the mill speeds be set that with a given temperature at the holding table the proper temperature will be produced after the last pass.

While there may be some variations in the set-up of equipment for taking the temperature of hot moving metal the above layout will cover the conditions of most mills.

PICKLE LINE TEMPERATURE CONTROL

The next unit of operation for which instrument and controls are necessary is in continuous pickling lines and the batch picklers. With the development of the continuous line of covered acid and hot water wash tanks, and the accuracy of governing solution concentrations, it has been entirely fitting that pickling control should have been developed far beyond its early conception of thermometer controllers. When it is realized that most continuous pickling lines are to be operated with the temperatures held within plus or minus 3 degrees it can be realized that the equipment once used for continuous picklers would not longer be satisfactory. The prime essential is accuracy and this means thermocouple and potentiometer measurement of the temperature. No less than the best equipment should be installed for this duty even though it is not an exact metallurgical heat treating process. The cost of acid and steam is enough to warrant exact control even if the metal surface treatment did not. All of the new continuous pickling lines have been equipped with potentiometer controls and the results have been most gratifying.

The second problem in pickling temperature control is one of maintenance. Any equipment subjected to the acid fumes ordinarily present, even in the covered pickling line installations will have enough corrosion possibilities that it almost requires that no open type of contacting or no exposed thermocouple junctions can be permitted. The best type of equipment for this service is one which embodies mercury-in-glass switches and a thermocouple installation which provides a continuous connection from the hot junction of the thermocouple to the recording and controlling instrument. Recording is mentioned as well as controlling because it is the general feeling that the records are an essential part of the control.

The matter of thermocouple location is important in pickling control because the thermocouple should be out where it is in contact with continuous liquid movement and not set back in the wall or protected by especially heavy tubes which would increase the time lag of temperature detection. Since most of the thermocouples are made with protective lead sheaths which themselves must be protected against the possible filing action of the edge of the strip and at the same time permit the liquid to circulate around them, some very clever mechanical devices have been developed by the steel mill engineers in collaboration with the instrument companies to provide just this sort of installation.

The use of the radiant tube fired furnace for annealing has introduced some very interesting temperature control problems. A typical installation of this type of furnace is illustrated below.

ANNEALING DEPARTMENT

From the pickling line the material then moves to the cold reduction and annealing processes. Regardless whether radiant tube portable furnaces or in and out box annealing ones are used, the control required has almost always been automatic. However, regardless whether automatic or hand regulated the equipment should be properly grouped into central control rooms and properly protected against the dirt and dust usually prevalent as the result of the furnace movement and sand seals. There have been many especially fine installations worked out. The tendency in all recent installations has been to group the control of four to eight furnaces together and hence have a number of control rooms in the annealing department.

The use of the radiant tube fired furnace has introduced some very interesting temperature control problems which involve not only the metallurgical treatment of the steel but the protection of tubes against excessive temperatures. In so doing the best treatment on the steel is produced because, while excessive tube temperatures may not develop a fault in steel structure if they occur for short intervals only, they may overheat the edges of the steel and cause stickers in the outer coils or along the edges if the load is flat. It has been my privilege to have assisted in developing what I consider to be the ultimate in the control of radiant tube furnaces with proportioning firing in which control elements are introduced in the instruments for both tube and steel. The tube temperatures are regulated in the early portion of the heat but when the steel has reached its control point the control is transferred automatically to steel temperatures. However, if the tube temperatures should become excessive afterward as they sometimes do, this type of regulation permits the control to return to the tube thermocouple where it is held until the tubes are reduced to a safe temperature, after which the control returns to the steel. This recycling can take place as often as is necessary in order to properly balance out the heat input at control point and the tube temperatures. Finally the control is entirely in charge of the steel element.

On all furnaces of the radiant tube type there has been developed an interlock between tubes and steel temperature. In the type of furnaces requiring two position firing operation this interlock is affected so that if either tubes or steel are high in temperature the control valve is moved to its minimum flow position. The development of these central panel boards has also been enhanced by the development of special types of plug switches and receptacles for both thermo-couple and control circuits, all of which has materially aided in centralizing control operation.

In the control of radiant tube furnaces there has been developed a method with proportioning firing in which control elements are introduced in the instruments for both steel and tubes.

DEOXIDIZING GAS CONTROL

The annealing department contains a number of gas generating machines to produce the reducing atmospheres required for steel surface protection. The determination of the properties of this gas has been a particularly interesting problem. To solve it there has been developed a recording equipment of the thermo-conductivity principle which can be used to determine whether the gas is oxidizing or reducing as well as intensity of the reducing properties. Since the reducing properties of the gas are dependent on its hydrogen and carbon monoxide contents and since it has been found that these are correlated when developed at elevated temperatures, a recorder that can detect the quantity of hydrogen in the gas will really measure its effective properties as a reducing agent. The equipment should be arranged so that each individual generating machine can be analyzed as well as the gas in the main line.

NORMALIZING FURNACES

The continuous normalizer for strip or sheet steel will embody a number of zones of control and since it has been a generally accepted principle that, if the furnace for this purpose is over and underfired, each zone of control should have separate instruments for control zones firing over and under the sheet, hence, two controllers per zone. Because a normalizing furnace is usually subject to considerable load variation temperature controllers for this particular duty should be of the automatic load compensating type. The means of load compensation may be provided either in the instruments or in the valve mechanisms but it should be embodied in the control system so that valve position is independent of temperature position and can take any position that is required between its limits to maintain the desired temperature. These control zones may be extended down the furnace to provide blue annealing in the same unit, as well as normalizing, in which case they will provide records for the cooling zones when the furnace is used as a normalizer. If no combination with blue annealing is required multiple recording potentiometers will suffice for the cooling

zones although there is a possibility that future furnaces of this type may embody regulation of the cooling water to the last cooling zone.

There are several equipments on normalizers, which while not exact innovations, have not generally all been combined on the same furnace. It is the speaker's opinion that these units should be a part of every normalizing installation and they are listed as follows:

1. Single record radiation pyrometer for taking the temperature of the strip adjacent to the curtain wall at the end of the heating zones.
2. A recording tachometer to indicate the speed per minute travel of the strip is extremely important because normalizing is based upon time temperature functions.
3. A system of atmosphere analysis is almost an essential in modern normalizing furnace practice in order to determine the efficiency of burner setting, combustion regulation and furnace tightness. It is suggested that a number of sampling tubes be installed along the top of the furnace and manifolded to a recorder so that progressive analyses can be run along the furnace and areas of atmosphere definitely determined.
4. If the normalizing furnace accommodates very wide strip, an indicating instrument should be provided with thermocouples spread along the outside edges of the strip to determine if the lateral temperature distribution is correct. This instrument gives additional benefits in providing the means for thermocouple readings in event of current failure. This is accomplished by a system of self-disconnecting switches which normally connect the circuits direct to the recording and controlling units but which in an emergency can transfer the individual thermocouples to the indicator.
5. The fuel to this type of furnace as well as any other should be recorded and integrated on a meter located on the main panelboard.

INSTRUMENT MAINTENANCE DEPARTMENT

Because strip mill processes are exacting in their temperature control requirements and the equipment developed necessarily intricate, it is appropriate that our closing remarks be directed to the consideration of the care of the equipment. Very early in the planning stages of the mill the idea should be established that the care of the equipment is going to determine its final efficiency and that before operation, a department should be created for the purpose of maintaining the equipment and at that time someone should be designated to have complete charge of this work. If such a department is recognized before actual construction begins they will be in contact with everything that goes on in the way of installation and become entirely familiar with the equipment before it is actually used. Then when the mill actually does get under way, operating maintenance will be available, a system of periodic checking and servicing developed, spare parts on hand and an instrument laboratory set up for more extensive repairs than will be made at the panelboards and where an adequate supply of thermocouples will always be on hand for the annealing department, in particular.

Instruments have been built to be as substantial as possible, consistent with the values of the electrical energy measured but inherently they are not a heavy piece of mechanism. Therefore, the man to handle the maintenance of instruments should have special training. Some industrial instrument manufacturers conduct training schools for men sent in by their customers. A one or two months' course for the men in charge of instrument maintenance, preferably before the mill is put in operation, will pay an appreciable dividend to the management. Special emphasis is placed on this because the maximum return from the instrument investment is limited entirely by the arrangements provided to take care of it after installation is completed.

In fairness to the men who are to handle this work it should be recommended that separate instrument laboratories be set up in a clean, well-lighted room, which can be isolated from other work in the metallurgical or fuel laboratories. Here also can be located stores of charts, ribbons, ink, thermocouple wire and insulators, and instrument parts. Furthermore, a well organized instrument laboratory should include a complete thermocouple manufacturing department, the equipment for which a test furnace with automatic temperature controller includes a deflectional type of indicator for comparing new thermocouples against standard, a small wire straightener to prepare the thermocouple wires for beading, and welding equipment. A high respect for this instrument maintenance group will be inspired if the equipment is adequate and well-organized.

These are important factors in creating personnel pride which in turn is reflected in the light of improved service to the equipment and ultimate better product.

PART 2 - By R. H. ELLIS

▲ A FEW months ago at a meeting of the Iron and Steel Association in Pittsburgh, Professor Trinks, in reviewing 40-year progress of the Steel Industry, stated that, basically, steel was now being made much the same as in the past and that the greatest change was in the methods of production. Professor Trinks' most important change was indicated as the use of electric motors, and at this time it is intended to discuss, not the use of the motors, but to enlarge on the use of instruments which analyze the behavior of these motors.

Early mill installations of electrical equipment consisted of a wound rotor motor running at a continuous speed and the conditions affecting the operation of this motor were of little interest, except perhaps, to the electrical maintenance man. As a result, no visible signs of meters were to be found in the mill and very few installations boasted meters in the motor pit.

Therefore, the mill man in general had a great lack of respect for any meter or indicating device whatsoever, and insisted that rolling steel was beyond the need of such technical assistance.

However, things changed, speeds increased, accuracy of product was demanded, rough shod methods were condemned, and today the meter is an integral part of the mill, and as important as the roll.

The continuous hot strip mill, with its variable speed motor, now is equipped with central operating pulpits

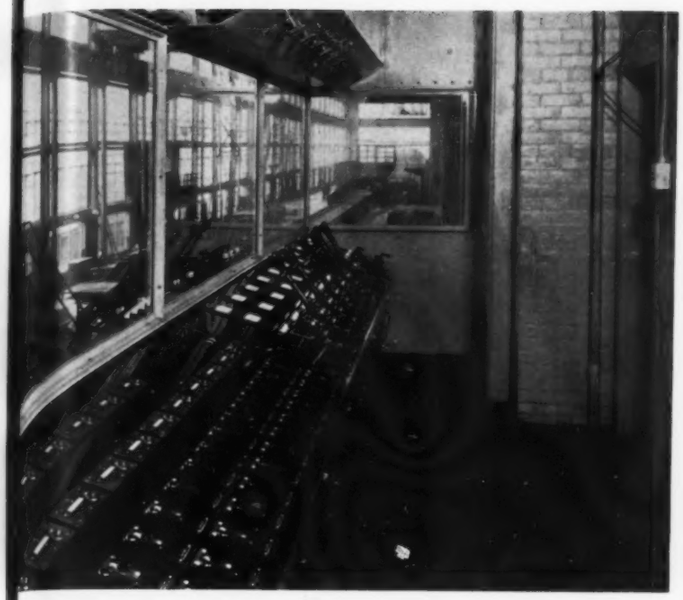


FIGURE 1—Drafts and speeds in the finishing mills are controlled from this operating pulpit.

FIGURE 2—Operating pulpit at the hot strip coiling end of the hot mill.

in which complete speed and power indicating meters are installed.

Figure 1 shows an operating pulpit; the operator here has control of drafts and speeds in the finishing mills. The first line of productimeters on the panel indicate to the operator the distance between side guards. The second line of productimeters give the screw-down readings on six finishing stands. At the end of the pulpit, meters indicating mill motor current and speed can be seen. Some of the steel companies contemplate having meters to indicate tension between hot finishing mill stands. These tensiometers operate with the looper mechanism that is part of the mill. The force exerted against the looper by the strip is calibrated to the tensiometer in pounds tension.

Figure 2 is a picture of a pulpit at the hot strip coiling end of a hot strip mill. Meters before the operator indicate speed and loads of hot run out table, hot

FIGURE 3—Schematic drawing of a hot flying shear arrangement.

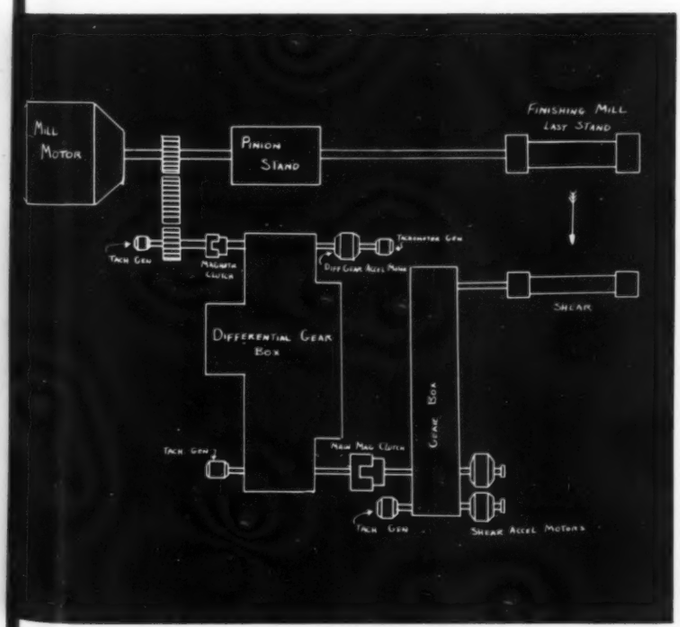
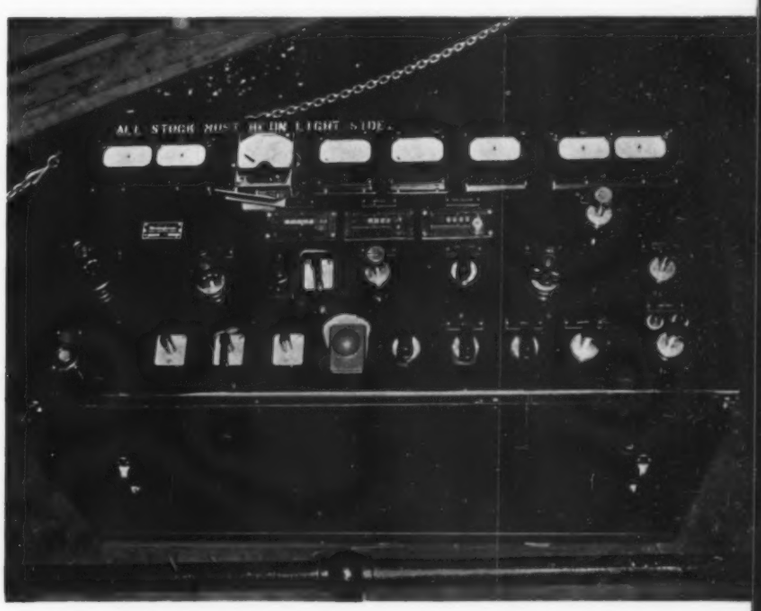


FIGURE 4—Here is illustrated one of the control benches on a reversing mill.



strip coiler, flying shear, etc. The speed of the runout table is dependent on the speed of the mill and for satisfactory coiling the coiler rollers must be running at the same speed of the runout table so that speed indicators are of vital importance. It is necessary that indication of the speed of the opening of the coiler arms is accessible to the operator as different gauge of strip and table speed require different speeds of arm opening.

Speed indicators are a necessary part of the hot flying shear. The speed of the mill and both sides of the main magnetic clutch must be known for satisfactory sheer operation.

Figure 3 shows a schematic picture of a hot flying shear arrangement. Here tachometer generators coupled to mill and shear motor drives and differential gear unit indicate through voltmeters calibrated in R.P.M. and F.P.M., the speed of each and the difference in speed between the gear unit and the shear knives. The operator must have visible indication of the speed of these parts so that he can adjust the running speed of the shear motors to correspond to the speed of the differential gear unit before the shear is to be operated.

FIGURE 5—Closeup of the meters on one of the stands of a tandem cold mill.

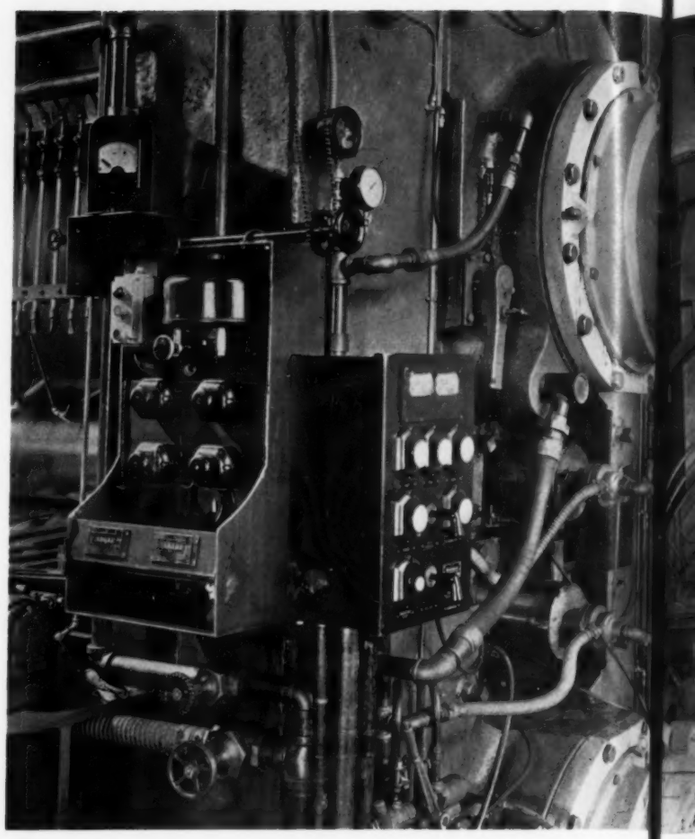


FIGURE 6—View of a cold mill stand with the meter on the flying micrometer visible at the lower left.

The writer has found the graphic meter to be a necessity in securing data for the computation of power curves for hot rolling steel.

The roughing mill, at its central pulpit, although not equipped with speed indicator, has its quota of power meters and, in the case of the edger rolls, their speed and powers are indicated. On slab pushers at broadside mills it is very important that load meters be mounted at the operator's pulpit to aid him in the proper operation of the slab pusher, as this machine is not supposed to do the mill motors' work and it is imperative that only the proper value of push be maintained.

Thus, electric meters have become an important part of the hot mills. The cold mills, although less spectacular, have perhaps enjoyed even a more rapid rise to fame. Speed jumped from one hundred to fifteen hundred feet per minute and above. Tension reels were installed, tandem mill back drags, automatic uncoilers, etc. Here the speed and power meters were again pressed into service, but also, automatic devices, unseen by the mill operator, are the real reasons for the success of the cold mill. Tension regulators, the heart of the cold mills, have been developed from the

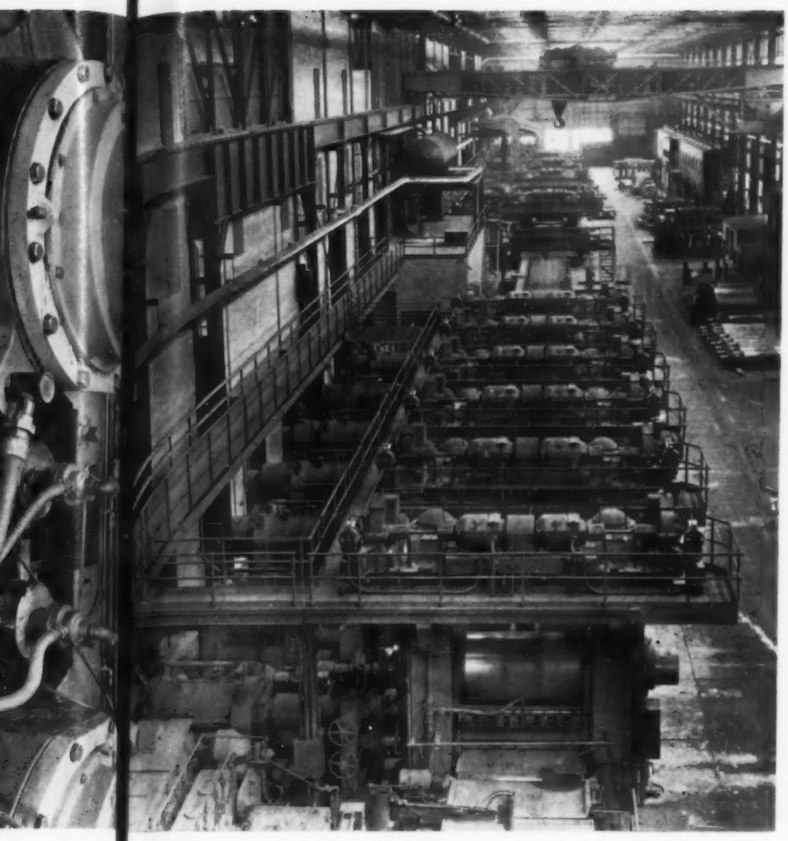


FIGURE 7—Six finishing stands of a hot strip mill showing the screwdown motors.

original Terrill regulator to high speed vibrating units. Tension measuring units are now available to read the strip tension between stands; flying micrometers to measure the thickness of the material being delivered from the rolls; all combining to improve product and speed up production.

Figure 4 illustrates one of the control benches on a reversing mill. Here the meters are used to indicate mill and reel motor currents and voltages, mill speeds, back and front strip tension calibrated in pounds and accuracy of gauge.

Figure 5 shows the meters on one of the stands of a tandem cold mill. Speed and mill motor current and tension between stands are indicated by these meters. There are two tension meters; one reading differential tension and the other, total tension. The tension roller can be seen at the left. Equal deflection at both ends of this roller give zero differential tension. When the differential tension indicates tension, it tells the operator that there is more tension on one side of the strip than on the other, which may mean improper setting of the screwdowns or non-uniformity of gauge in the entry strip.

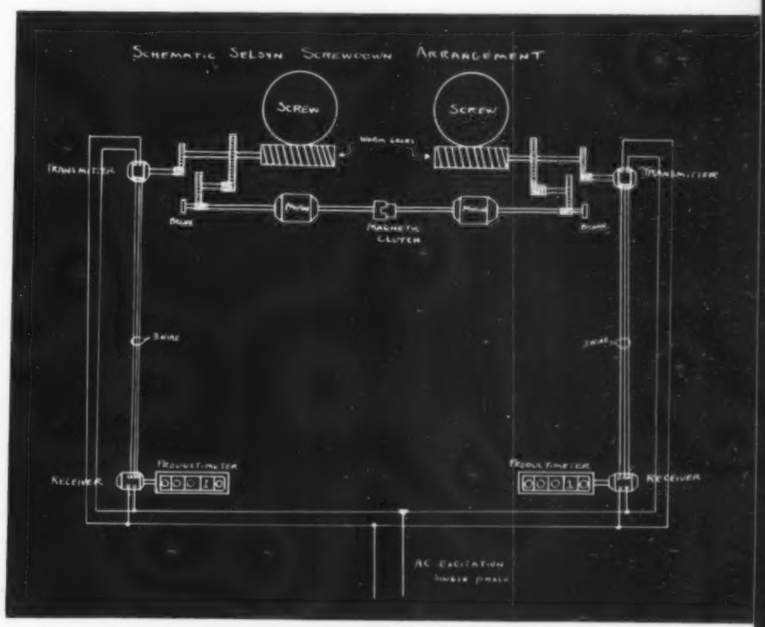
Figure 6 is a picture of a cold mill stand and the meter on the flying micrometer can be seen at the left hand corner of the picture. This meter is attached to a small shelf on the mill housing and indicates the accuracy of the gauge on the delivery side of the strip, that is:—it will indicate on full scale equaling .001" the amount of strip thickness over or under that desired.

Besides purely technical requirement, some aids for the physical benefit to the operators have been installed; one of which has been the use of the so-called "productimeter". This unit replaces the mechanical dial indicators which, with the advent of large housings, climbed into almost unreadable heights, and so, by the use of selsynties and counters, the screwdown indication was brought down to the operator's eye level. Beyond the physical benefits, this unit actually gives a better reading than the old dial. It reads, for instance, in cold mill work, directly by the use of numbers to one tenth of one thousandth of an inch and also reads the actual opening of the roll, whereas the old dial lost its value after one complete turn.

Figure 7 is a picture of the six finishing stands of a hot strip mill showing screwdown motors. These screwdowns are shown schematically in Figure 8 with their selsyn ties to productimeters. Here the rotors of the selsyn are connected to an a-c supply, usually 110 volts and the stator of one is connected to the stator of the other. When the screwdown is operated, the transmitter rotor changes its position with respect to the receiver. The voltages of the transmitter and receiver stators are then not equal and opposite. This causes current to flow, producing enough torque to turn the productimeter connected to the receiver. This torque is approximately 5 oz. inches for the small productimeter. The dial marking on the productimeter corresponds to the travel of the screwdown.

Productimeters are used on side guards similar to their use on screwdowns. The finishing mill roller

FIGURE 8—Schematic arrangement showing the screwdowns with their selsyn ties to productimeters, in use on the six finishing stands of the hot strip mill shown in Figure 7.



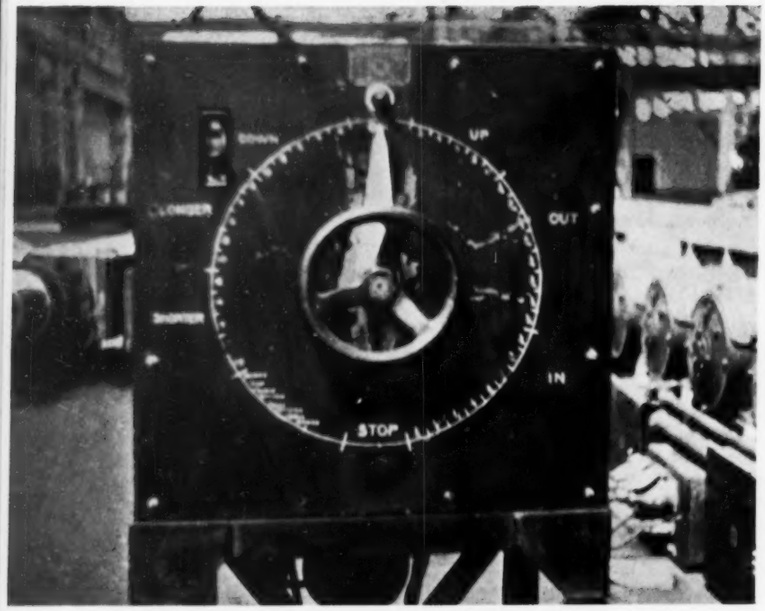
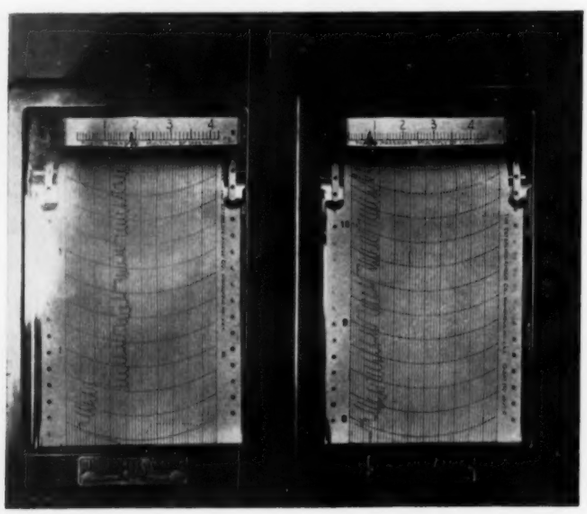


FIGURE 9—Blooming mill control pulpit showing master switches for control of mill, tables, manipulator, screwdowns with roll setting indicator and speed and load meters.

receives from the hot mill coiler, indication as to gauge and width of the steel by means of selsyn units connected to a large dial. This dial points out the condition of the steel in suitable words on the periphery, such as "light", "heavy", "ok", etc.

Productimeters with selsyns are also used on cold reversing mill reels to show the number of wraps of strip in the reel drum. Indication of the number of wraps on the delivery reel tell the operator when he

FIGURE 11—Two recording wattmeters calibrated in millions of pounds. Each of these graphic meters records the pressure on the side of the mill.



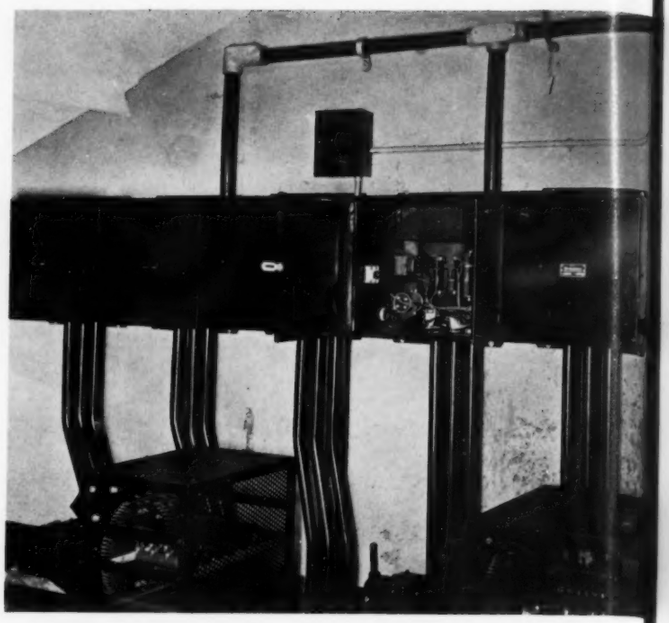
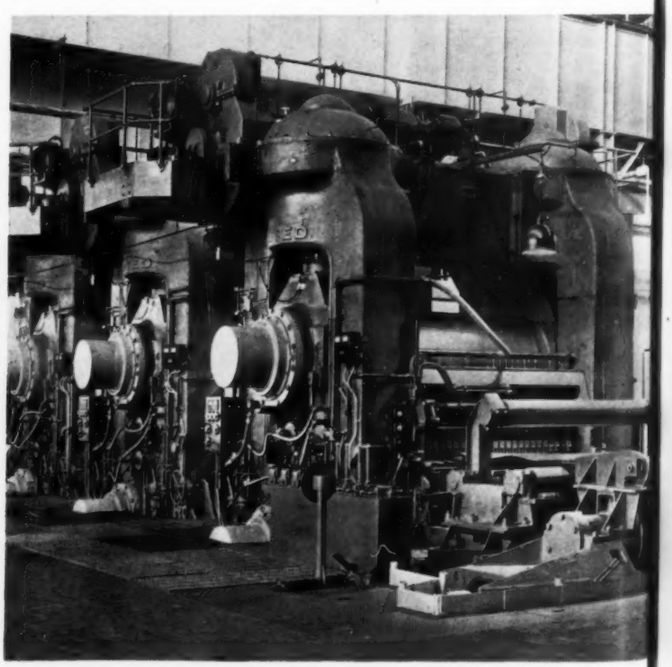


FIGURE 10—These six boxes house the pressure-meter equipment for a three-stand cold mill.

should slow down the mill so that the tail end of the strip will not be released from the entry reel.

Figure 9 is a picture of a blooming mill control pulpit showing master switches for control of mill, tables, manipulator, screwdowns with roll setting indicator and speed and load meters.

FIGURE 12—The indicating wattmeters calibrated in millions of pounds, attached ro the mill housing in view of the operator.



The large dial in the center of the picture shows the distance between rolls and from its indication, the operator operates the screwdown motors for proper drafts. This dial works by selsyn tie to the mill screw drive and it takes a little more than 15 oz. feet to satisfactorily drive the dial.

One very interesting and important development is the pressuremeter for indicating the static load on a mill housing developed by the screwdown. This unit, primarily developed during the time when bearing capacities were not all to be expected, and when too much load was detrimental to the bearings and shortened their life, has now, due to improvement in bearing design, found a new use. These units can be used to indicate the preset loading of a mill, which, when rolling cold thin material such as tin plate, can provide a means of "setting up" the mill for proper reduction without the use of trial coils. For example: Rolling from .072 in. to .010 in. in a 4-stand tandem mill, all the rolls are set below the zero opening, that is to say:—the mill housing is stretched. Now, after new rolls are inserted in the mill, the operator, from his past experience, knows the proper amount to stress his mill housing in advance of rolling so that the proper drafts are obtained.

The fundamental principle of the pressure meter is an ordinary Wheatstone Bridge circuit. When the bridge is unbalanced due to stretch in the mill housing, current flows through the detector transformer which is a special step down transformer. The current from the detector transformer now flows through the indicating and recording wattmeter coils. The reactance of the secondary circuit of the detector transformer is reduced by means of the series condenser which introduces capacity reactance into the circuit offsetting, to a degree, the inductive reactance of the watt meter coils. This lower total reactance results in an increase in sensitivity of the wattmeters to changes in current from the bridge.

The field coils of the wattmeters are supplied by the constant potential from the voltage regulator.

Figure 10 shows a box in which all the equipment is mounted, except the strain gauge and wattmeters that were shown on the previous slide. This illustration, incidentally, shows six boxes which house the pressuremeter equipment for a 3-stand cold mill.

Figure 11 shows two recording wattmeters calibrated in millions of pounds. Each of these graphic meters records the pressure on the one side of the mill.

Figure 12 shows the indicating wattmeters calibrated in millions of pounds attached to the mill housing in view of the operator.

DISCUSSION

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A. S. GLOSSBRENNER, Superintendent, Hot Strip Mill, Youngstown Sheet and Tube Company, Campbell Works, Youngstown, Ohio.

R. H. GELDER: First, I would like to congratulate Mr. Whitten on his interesting and instructive paper. I feel it can be studied by engineers and steel men for future developments.

While principally interested in discussing pickling and pickling control, I cannot pass up the first part of Mr. Whitten's paper concerning early development of instruments for continuous mills without comment. At the Ashland plant, of the American Rolling Mill Company, where we pioneered in continuous rolling we were forced to use conventional indicating and recording instruments. Automatic controls in most cases either were not available, or not adapted particularly to our use. This, coupled with the fact that on many of our operations we could not anticipate exactly what conditions were necessary to control, made our problems many times more difficult than they are today. Instrument makers cooperated with us, and from time to time additional control equipment was added. These additions, however, while quite satisfactory in no manner approach the well balanced systems that are being installed today.

Some of our operating units which now are instrumentized fully have recorders at one spot, control valves at some different location, and perhaps gas meters or flow meters at still a third location. The unit operator, to correctly do his job, is called upon to leave in some cases a very advantageous operating position to see what his instruments are doing. This unquestionably makes difficult the use of our control instruments.

Understand, these instruments referred to have been placed in the best remaining available space at the time they were located, but there is no question had we have known what we actually were going to use

in advance of the original building of the unit, a much more advantageous location could have been worked out. This brings me to the point in Mr. Whitten's paper stressing early planning for the proper location of instruments as being highly important. Much thought should be given this subject. You'll get more good, your control will be more accurate, your operating organization will want to use the instruments if they are placed conveniently near their job.

Another point brought out is consultation with the plant combustion engineer on instrument layouts. Fuel men play an important part in modern strip mills. It seems to us their assistance in discussing and selecting proper controls and meters, will pay big dividends by the economies and good practices which are bound to result from their line of reasoning.

Pickling and pickling practices have changed rapidly in the past few years. I believe I am correct in stating, at our Ashland plant we had the first large installation of strip picklers. Most of you perhaps know, that tied in with our strip picklers are strip normalizing furnaces which are used in conjunction with the picklers for a portion of our product. Thus, in some cases we have to pickle a product which has passed through a normalizer and such normalized products carry varied types of oxide, depending on previous processing. These added to the several types of mill scale, which we have to handle, presented to us a complicated continuous pickling problem. We were venturing into a new field where little was known about the control required to produce a satisfactorily pickled sheet of consistently uniform quality, and at a cost which would not be prohibitive. We learned very quickly that the maintenance of the proper temperature of various concentrations of pickling solutions was a major factor in our pickling practice, if any sort of a balance of correct solutions was to be maintained constantly. In the early stage of our development we were unable to secure control instruments that gave us a close temperature control which was essential to quality pickling. We tried several types of gas bulb thermometers but they did not seem to be successful and the cost of maintenance was prohibitive. Failures of this type of equipment were frequent and when they occurred it was necessary they be returned to the factory for repair.

The advent of the potentiometer controller operating from a lead sheathed thermocouple proved highly satisfactory in maintaining the accurate temperatures which we feel are required. Thermocouples with inexpensive lead wire present many advantages over the old system. Changes in location are easy to make, replacements when necessary can be done rapidly. If records only are necessary in some parts of the system, as many as six different couples can be recorded on one instrument. Extreme accuracy is obtainable. Last, but far from least, the whole system is rugged and should give long service with a minimum amount of trouble.

Before concluding my remarks, I cannot help but mention the wisdom of having a pyrometric service department built up of trained men who know how to take care of valuable equipment. Much money usually is expended in the purchasing of fine control systems. These control systems are intended to safeguard the product and the machines, or equipment, manufacturing the product. They are made to serve the operating organization the entire time the unit is working. To do this they must be maintained, and they must be understood. Much good can come from good control equipment kept in constant working order. Better quality, fewer losses to product or equipment and better operating costs should result from their use.

Perhaps you would like to know how we handle instrument service, and use of control systems in our plant. One of our senior metallurgist's is responsible for their maintenance and proper use. He has reporting to him a pyrometer service foreman, who in turn has seven service men under him with an A or B rating. These latter men visit every installation of control equipment every day, removing charts, properly identifying same and delivering to department superintendent. At the time the chart is removed the instrument is given a quick check up and minor adjustments made if necessary. Periodically every instrument is taken into the pyrometer service laboratory, cleaned and checked up. This service is maintained twenty four hours a day, and instrument or thermocouple failures corrected quickly. Our system prohibits anyone other than a pyrometer man making any adjustments to an instrument, removing a chart or making any change whatever in a control system, except, of course, regular operating changes of temperatures or conditions necessary in the manufacture of the product. This has the good feature of placing the responsibility of instrument care on one group. We believe this results in better and more rapid maintenance. Due to the fact that we do have twenty four hour service an operator who has any portion of a control system fail must call the pyrometer service man at once and so indicate it on his operating record. We are told by instrument companies that we have in general better records, fewer major failures due to excellent pyrometer service men. We believe it pays big dividends in good quality, mainly because our operating organizations are sold on control systems and thoroughly believe they are doing an accurate job of controlling.

J. R. McDERMOTT: Instrument maintenance in the modern strip mill has become a very important part of the general scheme. Pyrometers and tachometers especially have assumed the status of operating tools and are expected to deliver the same accurate and dependable performance as gauging micrometers. To maintain that standard, instruments must be checked and services by thoroughly trained instrument groups. This maintenance work may be divided into three parts:

(a) Purchase and installation.
(b) Repair service.
(c) Testing and checking.

Purchase and installation of new equipment should be co-operative with the engineering staff, who may be very helpful in planning the best wiring and construction features.

Specifications for purchase should include the type of equipment and accessories which are as simple in operation as the process will permit. Good instruments, improperly installed, will soon become poor investments.

Repair service, based on 24-hour operation, can be conveniently organized by dividing the plant into sections and assigning men to a particular division. Through follow-up records the supervisor can schedule cleaning and checking activities. On completing the schedule, inventories of spare parts and supplies in departmental field lockers may be put in order before the next schedule becomes due. Successful repair service requirements depend on the average age of the instruments, the location of the equipment, and the company policy in allowing the Maintenance Department to manufacture thermocouples, repair motors, and repack automatic steam valves, etc. Adequate spare parts and supplies, stored in lockers at advantageous points throughout the plant, are found to be valuable in increasing repair efficiency.

Testing Service. Instrument tests are based upon specifications furnished by the U. S. Bureau of Standards. A certified thermocouple with a number of secondary standards, portable test meters, a calibrating furnace, and a reliable optical pyrometer, comprise a good set of testing equipment. Hi-speed radiation units can be satisfactorily checked with optical pyrometers and supplemented with checks on calibrating boxes. Equally important is the daily inspection of water and air supply to the pyrometer cooling jackets. Other meters throughout the plant can be readily checked with portable potentiometers. No test is complete, however, unless the circuit is inspected for worn insulation, loose connections, and burned-out protection tubes. The results of all tests should be tabulated and filed for future reference.

The foregoing is a summary of daily routine. To achieve the best results from instruments, the men selected for the work should have initiative and technical training. For example, to service high speed radiation pyrometers employing amplifying circuits requires not only technical skill but the ability to quickly recognize conditions that may be detrimental to good operation. A certain amount of patience is an excellent qualification, too, which will not be amiss when making delicate adjustments.

Aside from routine duties, the supervisor should confer with department superintendents regarding the performance of present equipment, suggest improvements, and recommend for purchase the latest developments in the instrument field.

E. C. McDonald: Mr. Whitten's paper has very thoroughly described the instrumentation of a strip mill and should be of much value to anyone confronted with a strip mill instrument problem. I don't believe we can stress the importance of instrument care too strongly for incorrect and unreliable instruments may cause large losses and poor quality of product.

Mr. Whitten has asked me to discuss the control of a normalizing and blue annealing furnace, so I shall briefly describe the layout on a furnace of the hot alloy shaft disc type recently installed to heat sheets and strips up to 94 inch width with natural gas.

The furnace is sixty feet long with an internal width of nine feet, and is divided into three zones, each of twenty feet, formed by refractory curtain walls extending across the furnace. Each of these zones has separately controlled burners firing above and below the work. There is an additional refractory curtain separating the third or last zone into two smaller zones of approximately nine feet each.

The control and instrumentation consists of three recorder controllers equipped with thermocouples; one for each of the three major zones. These controllers are designed to give proportioning control with automatic correction for variations in loading. The three thermocouples extend through the roof of the furnace and are near the front of their respective zones. There is a fourth couple at the rear of the second zone which can be used with number three controller equipped with a double throw switch so that either number three or number four thermocouple can be used for control purposes. This arrangement is used so that when the furnace is blue annealing, the point of control can be changed.

For normalizing, number one zone is for heating; number two for soaking, and number three for cooling.

In addition to the thermocouple equipment and control, there are three lens type rayotubes connected to separate recorders, sighting on closed end target tubes. These target tubes are of sufficient length so they can be lowered very near to the work to fairly accurately represent the sheet temperature. They are located in one plane across the furnace midway in the rear half of third zone. Closed end tubes were used because this furnace may at times have a luminous flame atmosphere through which the rayotubes could not accurately sight. If at a later date a decision is made to operate the furnace at all times with a clear atmosphere, the ends of the target tubes can be removed and the rayotubes would then sight on the sheet itself.

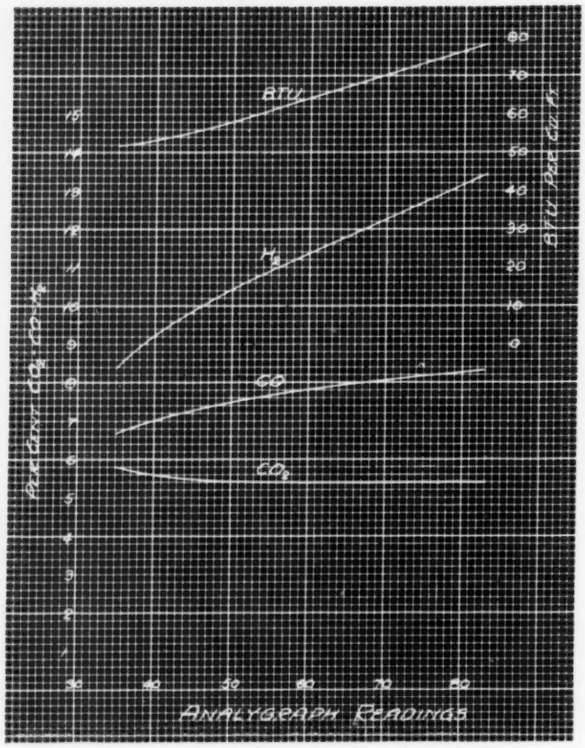
The reason for using three of these tubes is to check the uniformity in the steel to insure uniform heat in a very wide sheet. The recording instrument connected to the center rayotube is also a controller and may at a later date be used to control the zone in which it is installed directly from sheet temperature.

Briefly, the complete equipment as installed gives a temperature control of furnace atmosphere from thermocouples and a check on the work through the use of rayotubes. In other words, the thermocouples control the temperature of the furnace, and the steel temperature itself really governs the speed of the work.

Other instruments on the furnace are a tachometer; the usual pressure indicators; and an integrating and recording flow meter.

E. B. Dunkak: It is not necessary for me to emphasize to this audience the necessity of maintaining a continuous supply of protective gas of controlled characteristics, for regardless of the fact that steel sheets and coils are annealed on a batch basis, the annealing house and, consequently, the requirements for protective atmosphere gas, are on a continuous basis.

At Sparrows Point the atmosphere gas generators are provided with carburetion equipment which automatically maintains a constant volumetric ratio of fuel gas and atmospheric air, with orifice meters indicating at all times the rate of flow for the fuel



Stabilized analysis for 510 Btu. coke oven gas reformed in an Atmos-gas producer.

supply, combustion air, and generated gas discharge. The attendant can readily check these ratios with a casual glance.

As a further safeguard, an analygraph installed in the annealing house instrument room draws a continuous chart resulting from the continuous sampling of the contents of the atmos-gas line.

By adjusting the carburetion equipment to various air-gas ratios and analyzing the resulting atmos-gas samples, a graphic record has been made, showing the relation between the analygraph scale readings and the CO_2 CO, and H_4 content of the protective atmosphere gas. Thus, having established this information, it is merely necessary to set the carburetion equipment to give the desired analygraph reading with assurance of the correct atmos-gas analysis.

There has recently been developed a further refinement in the form of an absolute control on which patent protection is being secured. By this the analygraph and the carburetor are linked together through a proportioning type drive mechanism so that the analygraph acts as a controller as well as a recording indicator to automatically adjust the proportioning ratio of the carburetor to maintain a constantly undeviating control line. In this manner any changes which might occur in the thermal content and/or specific gravity of the incoming fuel gas, or in gradual frictional increase in air line due to clogging filters, or variations due to changes in rate of flow due to increased or decreased demand for the protective gas are automatically compensated for.

It is, of course, necessary that the carburetion equipment be of a design that is sufficiently sensitive and flexible to lend itself to this type of adjustment, but as such equipment is available, it is now possible to have protective atmosphere generation equipment truly automatic in its operation.

P. F. KINYOUN: I wish to compliment Mr. Whitten on his able presentation of this paper, dealing with the application of instruments for the modern strip mill. In general, I agree with the applications as outlined and wish to state that even though the Lackawanna Plant of the Bethlehem Steel Company installed one of the earlier wide strip mills, it is equipped about as outlined in this paper. The planning and laying out of this instrumentation program progressed along with the layout of the rest of the machinery.

As a matter of information, I will give a brief outline of the instrument applications at the hot and cold strip mills at Lackawanna:—

1. *Slab Reheating Furnaces.* These furnaces are completely equipped for all zones with fuel air ratio control on both the fuel gas and the fuel oil. Aside from this ratio control, each furnace is equipped with a proper furnace pressure regulator, recording fuel meters and a recording potentiometer, which measures the temperature of the flue gases entering and leaving each recuperator and the temperature of the preheated air to the furnace.

With the knowledge of this preheated air temperature, we are able to manually operate a cold air inlet to the hot air fan to prevent overheating. This can be done automatically, as suggested in the paper, but has functioned well in our case on a manual basis, there having been no fan replacements since the mill started in January 1936.

2. *Normalizing Furnace.* This furnace is under complete temperature and fuel air ratio control, in the three zone heating portion and has four points of temperature recording in the cooling zone.

3. *Batch and Continuous Picklers.* Both the acid and hot water vats on both types of picklers are under automatic temperature control, this being accomplished by use of lead sheathed thermocouples inserted in monel protecting tubes and located at the proper point in each vat. Indicating potentiometer controllers operate in conjunction with these couples and serve to maintain the temperature of the bath at a constant point.

4. The atmospheric temperature in the cold mill, the processing and shipping building and the continuous pickler department is maintained uniform by thermostatically controlled unit heaters; also in the hot mill building and plate finishing building, we have unit heaters fired with Bunker "C" fuel oil, with temperature control.

Another feature brought out in the paper, is the high speed temperature measurement of the steel leaving the hot mill rolls, which is incorporated in our mill layout.

With regard to instrumentation and temperature control in the annealing department, this was installed along the same lines as recommended by Mr. Whitten. This department includes 44 radiant tube

annealing furnaces and 133 bases. The furnaces are arranged either 4 or 5 to a group of 14 bases and each group of 14 bases has located adjacent to it, its control potentiometer room. This control room allows any furnace in the group to be placed and operated on any base. Each furnace is provided with its own 4 record recording potentiometer and 2 indicating controllers. The indicating controllers receive their temperature impulses from thermocouples placed in the steel being annealed and actuate the ratio control on each furnace. The control panel is arranged for switching both the control and thermocouple circuits and has been very successful in its operation. Our layout in the annealing department differs from that outlined by Mr. Whitten in that we made no attempt to tie in tube temperature with steel temperature for control purpose. With the type of fuel used at Lackawanna, we have found no need, as yet, for this extra control.

In addition to the application of potentiometers, both recording and controlling, we also included complete metering of all gaseous and liquid fuels, steam, water and compressed air, used in the various operations.

Definite knowledge of these items allows the fuel department and operators to use them with the most economy.

I heartily agree with Mr. Whitten's recommendation that the instruments, particularly the potentiometers, be serviced by an experienced pyrometer man. Such is the case at Lackawanna and this skilled man, who received several months training at the instrument factory, is provided with the necessary laboratory in which he keeps a stock of spare parts and other accessories that are necessary to keep this apparatus in proper working order. This instrument man also has charge of the manufacturing of thermocouples of which a great many are required per month.

H. B. Barber: The recording equipment described by Mr. Whitten has to date not been generally applied (as far as I know) to annealing department atmosphere-gas generators. It has, however, been applied to higher temperature operations such as the treating of tool steels.

The problems of the annealing department in a sheet mill have points of similarity to the higher temperature operation mentioned above, but the protection desired of an annealing atmosphere in a sheet mill requires protection over a much wider range of temperatures and, therefore, imposes additional demands on generating equipment.

In general, the atmosphere required for annealing sheets contains the same constituents as used in treating tool steel, some in the same ratio to each other and others in different ratios; and as the temperature operating range broadens, ratios of constituents that were of no importance in the narrow temperature range loom up with increasing importance.

The atmosphere gas produced from the common base gases generally used, such as Coke Oven Gas, Natural Gas, Propane and Butane, is composed of several constituents, namely, carbon dioxide, carbon monoxide, hydrogen, nitrogen, water vapor and oxygen.

The determination of the thermal conductivity of such a complex gas can, therefore, not be a true measure of the exact quality of such a gas. The best that can be done is to analyze for one constituent, say, hydrogen, and while this component will bear some sort of relationship to some of the other constituents and be of great value in operations over a narrow temperature range, it does not help in determining other ratios and quantities of other components that must be dealt with for protection over wider temperature ranges.

For example, the quantity of hydrogen will bear a definite relationship or ratio to the carbon monoxide, and the carbon monoxide will bear a definite relationship to the carbon dioxide and for a narrow temperature range at elevated temperatures; if these ratios are maintained the atmosphere is satisfactory and, therefore, a record of the hydrogen content is entirely satisfactory.

But now, let us see what happens when we must protect the steel at, say, 600° Fahrenheit.

We still want a definite carbon monoxide-carbon dioxide ratio, but we also want a maximum hydrogen-water vapor ratio and absolutely no oxygen, because as can be appreciated, time also enters the picture and while a minute trace of oxygen will cause no damage in a short time, over a period of hours the entire furnace charge can be spoiled.

Since at the elevated temperatures at which the atmosphere gas is formed some dissociation takes place, the gaseous products thus formed must be removed.

As the apparatus described by Mr. Whitten can take no cognizance of this element, and as the gas is further dried by the instrument before analysis, and since the principle of an instrument of this type implies a wide difference in thermal conductivity of one element from the other elements whose conductivities are for all practical purposes identical, it is rather doubtful whether any real value can accrue from the use of an instrument of this type, for the application under discussion. Since great care has been taken by manufacturers of atmosphere producing equipment to have these machines delivery a constant air-gas ratio, the only variation in the final gas would be due to the changes in the base gas itself, in either the air-gas ratio required or the specific gravity. As these variations are fairly well controlled at their source, there will be but very little variation in the major ratios of Hydrogen, Carbon Monoxide and Carbon Dioxide produced by the atmosphere generators.

The greatest need for instrumentation of the sort under discussion would be an apparatus for determination of the Dew Point and one for traces of Oxygen.

A potentiometer for the first mentioned above is now on the market and should be the most useful tool yet introduced for the aid and guidance of the operators.

A number of other instruments and controls are being successfully used in the annealing department to continuously safeguard against any interruption in the supply of the prepared atmosphere gas. Mr. Whitten has pointed out that the gas generating equipment normally consists of several units. Each

unit is designed to deliver the gas at a constant pressure from one third capacity up to full load. For uniform results, a constant pressure must be maintained in the atmosphere gas distributing line. Recording pressure gauges are, therefore, employed. If the number of annealing boxes or covers on the line exceeds the maximum capacity of the gas generating unit or units already in operation, the gas pressure in the main line drops to a safe minimum. When this point is reached, a mercury pressure switch, used in conjunction with the pressure recording instrument will actuate a light or an industrial horn warning the operator that another unit must be started up and turned on the line.

Other and similar automatic safety devices which go into operation in case of water, power or gas failure minimize the danger of damaging the gas making equipment and the many hundred tons of steel which are in the process of heat-treatment.

R. LAMB: We wish first to compliment Mr. Whitten on the splendid manner in which this paper was presented. We have all gained valuable information as to the possibilities of instrumentation in the hot and cold strip mills and the various processes through which such product passes.

We have a general interest in instrumentation throughout the mill and a particular interest in the subject as it applies to heat treatment, both annealing and normalizing.

The installation of cold reducing mills required large increases in annealing capacities, and in some cases the tube type furnace was chosen to be installed. At the time of installation, little or no experimental work or past experience was available as to the correct cycle to be used for the best response to heat treatment on this grade of product. When temperature instruments were required for these tube type furnaces, the best thought of plant engineers and instrument manufacturers was that the control of tube temperatures and the recording of a few work or steel temperatures would be sufficient. The tube temperatures were to be controlled at a constant value, and the work temperatures allowed to assume the curve that resulted from this setting.

Operators of the equipment were soon to learn that the problem was not that easily solved. Percent total reduction used at the cold reduction mills caused variations in the results obtained. While certain grades and gauges were satisfactory at such a cycle, other grades and gauges did not respond so satisfactorily. It was apparent that controlled temperature rise with possible variables in different parts of the cycle, together with the necessity of holding the work temperature constant for several hours would be necessary for some grades. With the instruments at hand, it was difficult for operators to get the desired results.

The larger instrument manufacturers soon realized that a so called standard instrument did not fit all applications, and despite the competitive angle of price, it was necessary to design instruments to fit the particular needs of different processes. As rapidly as the operators needs were made known, the larger instrument manufacturers met the requirements on test instruments, placed under actual operating conditions both to correct design and to determine if that particular design satisfied the requirement.

Proper control of steel temperatures during the soaking period or period during which the steel is held at a constant temperature, showed the necessity of controlling from tube temperature until the proper steel temperature was reached and then changing the control to the steel, as a constant furnace temperature would not maintain constant pile temperature in the steel. To maintain a constant soaking temperature without changing the control to the steel required almost constant supervision of tube temperature settings. When the manual change over was made, it was necessary to install an upper tube temperature limit device to protect the furnace tubes in the event the steel temperature control continued to require more heat when the tubes approached a dangerously high temperature value.

It is, we believe, needless to point out why the steel temperature was never used as the control point throughout the cycle. With such an arrangement the best results would be no better than an oscillating off and on control.

With the first instruments installed on the furnaces, it then became necessary to manually change the control from tubes to steel when the steel reached a predetermined temperature. The results obtained from this system of changeover proved satisfactory except when it became necessary for one operator to make the changes on several furnaces at the same time. A changeover might be made on one furnace when the actual steel temperature was several degrees below the set control point. When the changeover was made under such conditions, a rapid increase in tube temperature would result, with a return to normal values after a varying length of time. The increase in tube temperature carried with it a corresponding increase in steel temperature, the temperature rise being greater than the required degrees-per-hour as desired.

The automatic changeover type of instrument, with its auxiliary safety devices, is eliminating the difficulties experienced in making the changeover manually and works well with our present requirements.

We have had no experience with the relatively new centralized instrument and control panels; but such installations will doubtless reduce maintenance of instruments, controls, and switching or plug-in arrangements, will lower operating or producing labor, and will give an increased flexibility of the furnace arrangement. It might be added that with several controls in one location, irregularities are more easily noted than is possible when it is necessary to visit each instrument individually.

In reference to atmosphere controllers, or deoxidizing machines, we have done some work with recording the reducing values of such gas by a recorder of the thermoconductivity principle. We are not, however, set up to record continuously either individual machines, or the main line gas. We have found the thermoconductivity instrument very satisfactory for control of normalizing furnace atmospheres.

M. J. BRADLEY: The authors have given a fairly complete resume of the instrumentation on recent strip mills. The instruments and meters, if you please,

are simply tools by which the operators may correlate the temperature condition of the hot slab or strip, the mill speed, and the draught to reproduce continuously a uniform quality strip or sheet.

The temperature condition and the mechanical working of the steel changes its physical properties over wide limits, depending upon the amount of work done and the temperature at which the working is carried on. It is recognized generally, that the higher the temperature of the slab the less power is required to do the mechanical work, and the lower the temperature the more power is necessary to accomplish a like amount of mechanical work. However, if the temperature is too high or too low the quality of the finished sheet suffers. Without discussing the inflence which the working of steel at different temperatures may have upon the quality and properties of the finished sheet, in order to secure the greatest refinement of grain, either the initial temperature of the slab or the speed of the rolling should be adjusted so that the finishing temperature of the rolling will be above but as near the critical range of the steel as possible. The record of power used on the mill is a check on the temperature conditions of the slab. This explains why the Speedomax temperature recorder shown on one of the illustrations by Mr. Ellis was located in the mill pulpit so that the operator could compare quickly the records of both power consumption and slab temperatures. There is an optimum temperature condition of the slab to require a minimum power and a definite rate of working to produce a certain quality in the finished sheet.

On some of the mills listed, the temperature of the slab is measured by a Rayotube as it leaves the roughing stand. The temperature is recorded by a Speedomax located some distance away on a panel.

The same temperature also is indicated on a large dial located in the pulpit directly in front of the operator. If the temperature of the slab is much higher than that desired, the slab is held momentarily on the delay table until the temperature has fallen to the point where the slab should be started through the finishing stands. Thus each slab in any particular lot of steel becomes a special job finished at the same temperature, speed, and draught. Temperature measurements are made similarly on the runout table after the finishing stands and the speed of the table regulated so that each strip enters the coiler as near the same temperature as practical.

I might mention in passing, as a matter of historical interest only, that the first fast responding radiation pyrometer was developed around 1929, through the insistence of Mr. Louis Moses, superintendent of the Rail Mill at Sparrows Point. At that time Mr. Moses was studying the flow of metal between rolls running at different speeds in the rail mill. He could measure the roll speed and the draught but no equipment was available to measure the temperature of the billet as it passed through the mill. Finally a radiation pyrometer was developed which would measure the temperature of the billet as it was going through the various passes of the rail mill. It would reach the maximum temperature in approximately two seconds. At first these temperatures were indicated by the galvanometer on a potentiometer throwing a beam of light along a calibrated glass scale. The first spot of light was so small and travelled so rapidly that it was very difficult to read the maximum temperature indicated. The spot of light was subsequently increased in size to approximately one inch in diameter with a black streak vertically through its center position. This materially improved the readability of the indicator and was so favorably received by Mr. Moses that he or one of his cohorts named the spot of light after a popular movie actress of that date. Shortly afterward, he insisted on having these indicated temperatures recorded so that they might be filed with the rail order for future reference. After a couple of years more development work the Speedomax recorder was furnished for this and similar applications. Today the radiation type of temperature measuring pyrometer is standard equipment on all the modern strip mills.

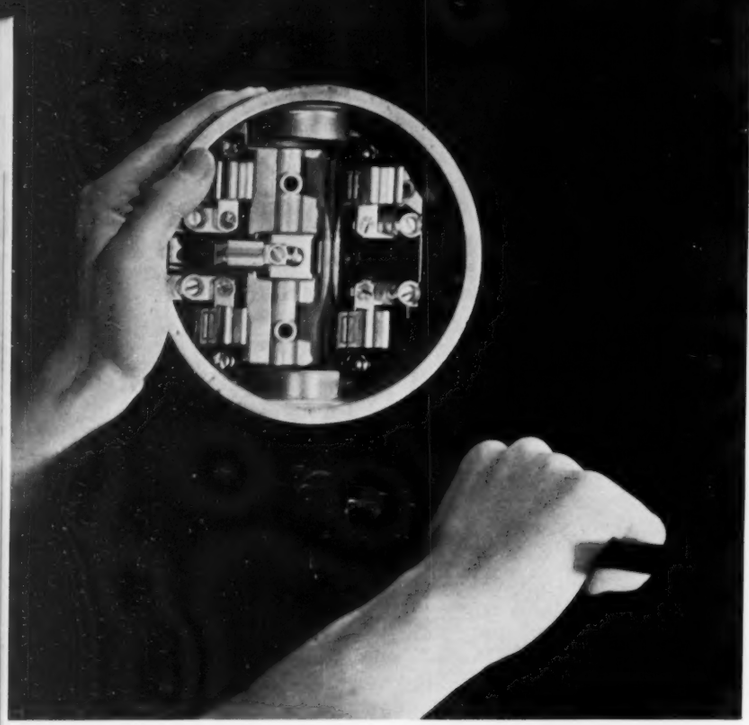
Finally, I might add, that the advantages of being able to measure the temperature of hot slabs, sheets, or strips, during processing, today, may in no small degree be credited to the insistence of Lew Moses to do the "then impossible" in 1928 and 1929.

G. E. STOLTZ: In pointing out the advantages of electric meters as used in steel mills, Mr. Ellis has done very well to refer to Professor Trinks' paper in which he reviewed 40 years of progress in the steel industry. Professor Trinks stated that the greatest change in the steel industry was the use of electric drive.

It was only after electric motors were used to drive mills that we learned a great deal about rolling steel, particularly in reference to the power required. If it had not been for electric meters, we would not know much more about rolling of steel with electric motors than was known when steam engines were used.

Occasionally steam engines were indicated, but in general for a given mill a certain size engine was known to be adequate. For instance on a 40″ reversing blooming mill it was known that a 55″ x 60″ engine would satisfactorily operate the mill. Very often the production on the mill was limited to the capacity of the engine. We remember one instance where we were requested to advise the capacity of the motor to drive a plate mill and recommend a 4000 hp. motor. The customers felt that this size of motor was entirely too large for the mill and pointed out that he had indicator cards which showed that the engine could not carry this capacity even for a momentary period. A study was made of the operation of this mill and it was found that on some occasions the speed of the engine dropped to as much as 40 per cent of its nominal speed. When the operators noticed the engine slowing down to this extent, they naturally withheld the steel until the engine had time to recover its speed. The mill was finally electrified with a 4000 hp. motor and a large flywheel and even with the flywheel occasionally this motor would carry peaks of 9000 hp. The tonnage put through the mill was limited only by the operators' ability to put steel through the mill and not by the capacity of the driving unit.

Another installation that came to our attention was a tandem two-stand bar mill where the roughing stand



Above—Operator installing meter socket in conduit. This is a five jaw circuit closing type suitable for voltmeter, ammeter and wattmeter, both a-c. and d-c. Below—Operator inserting an ammeter in socket installed in conduit. Upper right—Operator reading this type of instrument installed in high speed boring mill. Below left—The flexibility of the socket-type meter installation is evidenced in this illustration. An insert socket is used in connection with portable analyzer. In this instance the analyzer consists of a voltmeter, ammeter, wattmeter and power factor meter. On the top of the insert jack is mounted a watthour meter which will simultaneously register the Kw. hr. consumption.

and finishing stand are both equipped with the same size and speed engine and with the same flywheel. It was not then generally recognized that the work on the roughing stand was of short duration and very heavy passes and not such heavy work. With the knowledge we have today obtained from electrical instruments the horsepower capacity of a motor placed on the roughing stand would no doubt have been less than that on the finishing, but its flywheel would have been much larger and the speed of the roughing stand would have been much lower than that of the finishing.

One of the earliest and most important developments in the use of electric drive for steel mills was the motor driven reversing blooming mill equipment. When these equipments were first installed, it was necessary that the operator use great care in handling the controller. The first equipments were not as stable

as the ones designed today, and it was a very easy matter for the operator to change the fields of the generator and the motors so rapidly, that the equipment would be subject to heavy overloads. By the use of indicating meters, graphic meters and oscillographs, the performance of these equipments could be carefully studied and gradually improvements were made in the control and the design of the machine themselves so that today these equipments are operated by foot pedals.

The present day continuous hot and cold mills would not be possible, if it were not for the development of the present day electrical equipment, and this in turn would not be possible if we did not have available electric meters to study the performance of the equipment to drive these mills. I think in general we give all the credit to the development of the control and the characteristics of the motors themselves, without recognizing that these particular developments could not be made if it were not possible to study the performance of the equipment with electric meters.

In recent years it has been the practice to install large indicating ammeters outside of the pulpit in a hot mill to indicate the current load on the large direct current motors on the finishing end of the mill. This gives the roller on the mill who is responsible for the drafts on each individual stand an opportunity to note what load is being carried by each motor. I think this has done more to balance the loads of the mill than anything else.

When we look back there is no question but what a great deal of progress has been made on main motor drives, and I am sure this work will continue. Credit will have to be given to electric meters of the various types mentioned in Mr. Ellis' paper for this advance. The same degree of refinement has not been attained in the use of auxiliaries. There have been some very fine developments on individual applications, but too often auxiliary motors are applied by rule of the thumb. The reason for this is no doubt due to the fact that we cannot afford to place as many instruments on individual auxiliary motors as we do on the main drive. The development of the socket type meter should go a long ways to meet this demand without incurring the cost of having a full set of meters for each small motor. To accomplish this it is only necessary to install an inexpensive socket in the conduits to the motor. Instruments of various types are designed to be inserted in this same socket, that is on a direct current motor a socket would take either a direct current ammeter, or a voltmeter, and on an alternating current motor the socket would accommodate an ammeter, wattmeter, voltmeter or a watthour meter. The installation of this type of equipment no doubt will result in studies which will permit the installation of more closely rated motors and control as well as the installation of apparatus somewhat better fitted to the application.

A. J. FISHER: In the construction of furnaces, instrumentation should consist of the following all important factors.

1. Selection of the proper type of instrument.
2. Enclosed type mounting panels with all services such as air, electricity, etc., on the inside.
3. Training of personnel to calibrate and make repairs to the instruments.
4. Instrument repair shop.

Instruments should serve two fundamental purposes; (1), as a guide to the operation; and, (2), as a record of the operation. They should be placed in a handy convenient place for easy observation. Instrumentation should be engineered and completed in the drawing room rather than fitted into odd places in "the field" during construction.

A. S. GLOSSBRENNER: I have a very few remarks to make, which I believe are pertinent to the discussion of Mr. Whitten's very able paper. I do not want to leave the impression that I am being iconoclastic in what I have to say, as I do not want to tear down the ideal plans of instrumentation, which Mr. Whitten has described. However, as just a word of warning, it may be said that even with all of these instruments described and with the best of instrumentation layout, if the proper care is not taken, we, as operators, get nowhere; and also, that even with the best of care of the finest instruments that are now obtainable, we are still apt to run into trouble unless proper relations are studied out and held to in the use of such instruments.

In our particular hot strip mill layout, as some of you know, we have gone to the use of four instruments designed for temperature control in the mill run. We found this necessary as we experienced trouble from time to time in keeping certain products sold, which, so far as recorded information showed, should have been structurally correct. At such times when we went to the operating crews and asked for certain information on heating and finishing temperatures, we would find chart readings as prescribed, and everything on the surface of records according to Hoyle, with all instructions properly carried out.

Finally, in order to give a nicer control over finished structures, we found that we had to have two more than the original two pyrometrical recording instruments at other positions in the mill run, and that it was very necessary, in order to determine the degree of soak and the uniformity of heating of a particular piece of steel, to keep the relations of temperature at various positions through the mill within narrow limits. By considering the element of time in relation to temperature drops at various locations in the mill run, it has been found possible to control structures of the finished product to a nicer extent than had been the case before this relationship had been recognized practically. I would like to leave this one thought with all of you, that, whether you are rolling slabs into strip or rolling bars into rods or other product, if the proper use and proper relations of temperature that are recorded or indicated are not kept in mind, you are going to let yourself in for a lot of trouble.

SELECTION of INSULATED CABLES for STEEL MILLS

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INTRODUCTION

If we were asked to give you all the factors affecting the selection of electric wires and cables, we probably would have to ask your indulgence for two or three days, for there is a tremendous number of such factors. In this paper, the authors have attempted to give you the most salient points.

To a man who has been in the cable business and who manufactures cables, it is a wonder and a cause for congratulation that the men in the steel industry have been so fortunate in their selection of wires and cables, for there is quite a number of hazards in the installation and operation of cables in steel mills. Those hazards might include; for example, heating due to overload, the effects of heat due to surroundings; the effects of moisture, acids, alkalis, oil and other deteriorating influences; the effects of vibration, abrasion, impact; then, occasionally, on high-voltage cables, the effects of ozone, both internal and external, corrosive fumes and sometimes the effects of rodents.

It might be of interest to review the list of some of the materials used in cables: Copper, bronze, lead, zinc, and alloys of all sorts; rubber and its various compounds; heat-resisting, sun-resisting, etc.; asbestos either in felted, braided or inserted form; impregnated paper for high and low-voltage cables; rubber tapes; paints, varnishes, emulsions, asphalts, cements, shellac, waxes, braids; varieties of cotton, hemp, twisted paper, cellophane, cellulose-acetate, and host of other materials.

As far as the insulation itself is concerned, guesses are made as to its probable life. One says 20 years, another, 25 years. One person said, "Rubber insulation? Why, I know of rubber-insulated cables that have existed for 35 years". Another individual said, "Oh, I had some rubber-insulated cable in service that didn't last 18 months". Both are correct. Neither, however, mentions where the cable was used.

Now it so happens that the 35-year cable was a submarine power cable, and the water in which it was immersed prevented the temperature of the insulation from increasing very much. There is one fundamental fact we must bear in mind: Nature is so constituted that every rise in temperature of 10°C doubles the chemical activity. It makes no difference whether it be wood, rubber, paper or anything else. So, if a material is operated at approximately 35°C, it should last a great deal longer than at 75°C.

A few weeks ago, I watched a certain synthetic resin being mixed with oil and found that it had been churned for approximately 36 hours without any noticeable results. Each time, as they kept on churning and adding oil, it seemed to go a little more into solution and to become more and more bound together. It took approximately 10½ hours finally to make the solution. What I have in mind is that if you keep on reading this paper, I am sure that you will find the answers to some of the problems confronting you. I am sure, furthermore, that it may raise certain points in your mind which you may not have considered before, or that some point may be new to you and will suggest another line of thought, one that may prompt questioning the cable manufacturer for a new type of product.

▲ THE subject of this paper has been chosen in the belief that these are the items you would like to review and with the hope that this paper will be of help in your everyday problems. We want to show how these factors are important to you in selecting cables to make them more dependable.

Different engineers use different kinds of cable in a steel mill under practically identical conditions and they all work. But the engineers all must start with the correct application of the fundamentals of cable engineering in order to arrive at the best construction. If cables can be made to operate better and give less trouble, and if this paper will make it easier for you to know how to go about the solution of your problems, then its purpose will have been accomplished. Its purpose, therefore, is to review these fundamentals together with a discussion of some of the advances in the art of cable manufacture.

Cables in steel mills represent but a small percentage of the total cost but they are a very important link in the chain of equipment that turns out steel. Unless all the links of this chain are dependable, you are quite aware that a tremendous investment can remain idle. To keep the mill running, you feed it fuel by way of electricity through its cables. Don't cut its throat or choke it by taking chances with that small but important link in the chain. Witness a situation recently when a large new rolling mill was shut down for several hours on account of the mechanical failure of an important but comparatively inexpensive pump. Cables must be dependable. Even the very best possible cable construction would not be prohibitive so long as the mill keeps running; no more than a coat of paint on a house is too expensive, so long as it protects the house from decay.

In the selection of insulated cables, it should constantly be kept in mind that all the component parts of the cable are equally important. Doubling the insulation thickness is one way to obtain more reliable operation, but you will agree it is not the only requisite for that extra factor of safety. Balanced design is paramount, to obtain the best results. And what is

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meant by balanced design is this: Selection of a cable make-up that will meet *all* the requirements of installation and operation from the time it is taken off the reel until it is scrapped. All these requirements must be studied and that brings us back to the purpose of this paper. After all, of what avail is it if a cable with extra insulation or an oversize conductor fails from some kind of external damage not sufficiently considered before the cable was purchased? You wouldn't build a new home without painting it nor would you put in an elaborate kitchen and no living room. To be most useful, a cable must have a balanced design the same as your house.

Sometimes there is more than one cable suitable for the job. No doubt, you have all had the experience of living in more than one house that was suitable too. In the end, the final choice depends on personal preference, economy or convenience. The same is true with cable.

In any discussion of this subject, the factors involved in cable selection naturally fall into three groups.

1. Design
2. Installation
3. Operation

Each has its distinct effect on the success of any cable selected.

1. DESIGN

The factors in the design of a cable which determine its ability to keep the mill running are:

Operating voltage and frequency, a-c or d-c.
Grounded or ungrounded neutral
Ambient temperature
Duct aerial or submarine installation
Kind of insulation
Shielded or non-shielded type cable
Daily load cycle
Single or multiple-conductor
Type of sheath or protective covering
Conductor size and current-carrying capacity
Cable diameter

2. INSTALLATION

The conditions of installation naturally have a direct bearing on the application of the cable for satisfactory results. Briefly, these conditions must be recognized in selecting the proper cable design and the most favorable methods and practices should be followed when the cables are installed. Some of the factors are:

Size, location and condition of duct banks, conduits other cable locations.
Presence of nearby furnaces, steam and hot-water pipes or hot spots.
Presence of moisture, solvents and corrosive ingredients
Freedom from mechanical damage during installation
Freedom from vibration
Training of cables
Jointing methods and workmanship
Ventilation
Selection and installation of potheads when required
Grounding and bonding of lead sheathed cables
Fireproofing

3. OPERATION

Methods of operation have a decided influence on reliability, maintenance and cable life. After the cable has been properly designed to meet its requirements and installed in a manner to insure safe operation, we believe you will agree it is only good business to protect them from abuse and unsafe practices. Some of the factors of importance are:

Protection against overload and overvoltage
Protection from external heat
Protection against mechanical damage
Routine inspection for protection against corrosion and electrolysis (if metallic sheath is used)
Cable sheath grounding and bonding.

	Rubber	Varnished Cambric	Paper-Lead Solid-type	Asbestos & V-C	All Asbestos
Maximum Conductor Sizes					
Single-conductor, Mc.m.	3,000	5,000	5,000	5,000	5,000
Three-conductor, Mc.m.	1,000	1,000	1,250	750	750
Maximum Permissible Conductor Temperature (deg C)	50-75 (a)	75-E (ordinary) 90-E (heat resisting) (d)	90-E (b) 90-E$\sqrt{3}$ (c)	100-3E	200 (dry) 125 (moist)
Maximum Voltage (3-phase kv)					
Grounded Neutral	8-25 (e)	28,000	75	7,500	600
Ungrounded Neutral	5-15	17,000	35	7,500	600

E = Phase to phase voltage in kv.
(a)—Depends on kind of insulating compound.
(b)—For non-shielded (belted) type cables but not over 85°C.
(c)—For 1-conductor and multi-conductor shielded-type cables, but not over 85°C.
(d)—But not to exceed 85°C.
(e)—ASTM compounds (30% AO, Performance) rated at 8000 volts maximum; special compounds up to approximately 25 kv 3-phase, occasionally higher, according to manufacturer's recommendations.

FIGURE 1—PRACTICAL CABLE LIMITATIONS

1. DESIGN

The design of a cable amounts fundamentally to selecting a make-up that will meet *all* the requirements. Aside from making proper provision for the conditions under which the cable is installed, adequate protection of the insulation and overall dependability, the balance of the design in a power cable is directed toward finding the desired regulation and current-carrying capacity.

These factors affecting current are reviewed here because they all must be considered in order to obtain the correct answer. The other features are discussed later in the paper.

CURRENT-CARRYING CAPACITY

All of the calculations for current-carrying capacity are based on temperature rise as the controlling feature and that is what it is all about. For example, in a duct bank buried in the earth, the temperature rises from the surrounding earth through the duct bank to the duct wall; then there is another temperature rise from the duct wall to the surface of the cable; and, lastly, from the surface of the cable through the insulation to the conductor. Reference to Figure 2 indicates the three steps usually considered in calculating temperature rise. For cables in air, there are only two steps instead of three.

The amount of heat generated in the conductor from the energy losses is added to the heat in the insulation from the dielectric losses and these two items make up the total amount of heat to be dissipated. It is fundamental that the determination of conductor size is based on this train of temperature rises. Now, if the surrounding earth or air is cold, the total temperature rise permitted is a maximum and a certain conductor size can be used without harm to the insulation. If, however, the surrounding earth or air is warm, the maximum temperature is still limited to that determined by the kind of insulation used (Figure 1), and, therefore, the total temperature rise is smaller. The net result is that a larger conductor size must be used in order to keep the maximum temperature within the prescribed limits. If the permissible temperature rise is too small, because of a high ambient temperature, it may be impossible to use a cable at all, or it may be necessary to re-route the duct line through a cooler section.

It is important to remember that the hottest part of the cable run is the one which determines the maximum current-carrying capacity for the entire cable. For example, if a cable runs past a furnace where the temperature of the earth is 40°C, instead of 20°C, its current-carrying capacity is considerably reduced, even though the balance of the run is cool. Let us take a concrete case, such as six 3-conductor, 4/0, 15 kv. non-shielded type, V-C insulated cables running in a duct bank in the earth with a normal ambient earth temperature of 20°C, (68°F). At 50% load factor, each of the conductors in each of the cables will carry 187 amperes or 4,470 kva. per cable. Now, if the duct line runs past a furnace, for say 30 or 40 feet, and the earth temperature is raised to 40°C, (104°F), instead of 20°C, the capacity of each cable would be reduced to 62%, or only 116 amperes instead of 187. This shows very readily how important it is to consider temperature rise.

Now let it be said emphatically that current-carrying capacity cannot be taken from an ordinary table, such as found in the National Electric Code. The reason

is that no one table has ever been compiled that would take into account all the different factors that must be considered in order to arrive at the correct answer. The calculations must be carried through, and they must be carried through from beginning to end. In this job, there is no "royal road to Dublin".

If the engineer does not have sufficient time to run through these calculations, and if his cases are amongst those ordinarily considered, correct tables for current-carrying capacity have been calculated for convenience and are available in several publications. These tables have been calculated on the same basis as stated above, namely, with all the factors in mind, and the amperes shown in these tables are good only for those conditions shown. If you have any other conditions that do not fit these tables, then the values therein are not correct for those other conditions.

Why do we lay so much stress on calculations for current-carrying capacity? Because there is so much guessing done about this important point and guessing is very apt to lead one into trouble. Correct values for current-carrying capacity are important to steel men, because then, the cable will not operate too hot and possibly fail. At the same time, if you have the correct conductor size for the load to be carried, you will not have to pay unnecessary money for a larger conductor that might have been estimated and which, if not needed, is merely wasting money.

All the factors required for calculating current-carrying capacity are listed in the publications referred to. But do not let these calculations scare you. Fortunately, when one has gained a little practice, the work is simple and rapid and can be done by an engineer inexperienced in cable design.

The following are the factors that must be determined before current-carrying capacity can be calculated.

OPERATING VOLTAGE

The first thing to be decided is: How much load is to be carried, and what shall the operating voltage be? The engineer on the job must determine the total load, diversity factor between loads, provision for future growth, and similar items.

The operating voltage is determined by what voltage is already available, what is convenient, length of run and regulation. Reference to Figure 1 indicates that there are rather definite maximum sizes and preferable insulating materials for use with various combinations of load and voltage. Obviously, it is necessary to consider kind of insulation at the same time as voltage because some insulations are more suitable for higher voltages as discussed later.

In steel mills, 6600 volts is used as both transmission and distribution voltage. In transmission (high-voltage) systems, the energy losses and current-carrying capacity are usually more important. In distribution (low-voltage) systems, voltage regulation generally is the chief factor upon which voltage and conductor size is based.

If the current to be carried is so great as to make conductor sizes too bulky and the cable too expensive, or, if the run is long enough to cause prohibitive regulation, a higher voltage is preferable.

Ordinarily, voltages up to 550 volts a-c are used for small loads over comparatively short distances. 2300, 4000, 6600, 11,000 and 13,200 volts, three-phase, are used for the heavier loads and for longer distances. This is in line with other industry practice besides steel mills. When selecting the voltage, keep in mind the total cost of the installation, including the cost of fuses, circuit breakers, switches, ducts and conduits, besides wires and cables and their energy losses.

The advantage of higher voltages lies in reducing transformer and feeder losses and making it possible to carry comparatively heavy loads a considerable distance at low loss and with small voltage drop.

GROUNDED OR UNGROUNDED NEUTRAL

Here is an item often overlooked in designing a high voltage cable, and is one of those that must be considered in selecting insulation and its thickness. Its importance is due to the fundamental consideration that there is better control of, and less variation in, voltage between ground and the line wires when the neutral is grounded. If it is ungrounded, changes in load, surges, partial or complete grounds on any one of the line wires, results in the shifting of the neutral, with a corresponding difference in the voltage between ground and each of the line wires. For this reason, the cable manufacturers and the industry in general have set up insulation thicknesses for all cables above 4000 to 6000 volts, with less thickness for grounded neutral than for ungrounded neutral.

Operation with a grounded neutral is disliked by some because the failure of one leg grounds it, causes a short circuit and stops operation. It is true this is a distinct disadvantage, but there are likewise disadvantages to operation with an ungrounded neutral; such as those already mentioned; also, the requirement of a greater insulation thickness, and therefore higher cable cost.

AMBIENT TEMPERATURE

Ambient temperature must be known before the conductor size can be selected and is important because it is one item that determines the maximum permissible temperature rise and, hence, thee urrent-carrying capacity. It is considered as being the temperature of the earth, air or water which can be used as a safe value for the dissipation of heat from the cables the year round. In this latitude and south to a line drawn between Baltimore and San Francisco, the ambient earth temperature is usually considered as 20°C; air, 40°C; and water, 15°C under summer conditions. However, the actual ambient should be determined, if possible, for any installation under consideration.

KIND OF INSULATION

The most common insulating materials, as is well known, are rubber, varnished-cambric and paper. These and asbestos are all used for the low and intermediate voltages. Paper is more frequently used for the higher voltages, say 11-kv 3-phase and higher. Cables with all types of insulation are equally depend-

able when properly designed for the conditions to be met. Production losses, incurred by interruptions, may cost more than the most dependable cable construction, hence the proper kind of insulation is important to you.

For power and lighting circuits up to 600 volts, rubber-insulated wires and cables are usually employed, especially in the smaller sizes, because (1) they are easily pulled into conduits and raceways; (2) they are flexible; (3) the insulation offers moisture protection; (4) 600-volt conductors can safely and dependably be insulated with rubber; (5) they are easily spliced and tapped; (6) they can be terminated without potheads.

It has been said that more progress has been made in rubber compounds during the last 10 years than during the previous 30 years.

With the aid of modern discoveries, particularly anti-oxidants and accelerators, there have been developed additional compounds to meet nearly all service requirements, and the list is still growing. Among these compounds are:

A longer aging and greater heat-resisting compound than that contemplated by ASTM Type AO, known as Performite
High-voltage ozone-resisting compound
Network cable compound
Heat-resisting rubber compound
Moisture-resisting compound
Flame-resisting building wire compound

Several well-known rubber compounds are available for ordinary moderate conditions of temperature, moisture and so on, such as Code, Intermediate, and 30 percent. Special compounds are used for more severe conditions and where greater life and dependability are demanded, and are offered by the manufacturers under their own specifications.

Varnished-cambric-insulated wires and cables also are used for this voltage, and some of the common reasons are:

1. When larger-size conductors are required, varnished-cambric usually affords greater flexibility.
2. It is selected by many for hard service, and is preferred in some industries, such as steel mills.
3. It permits higher copper temperature than some of the standard rubber compounds and, therefore, makes it possible to carry more current without shortening cable life.
4. Varnished-cambric cables can be terminated indoors without potheads.

High temperature V-C insulation is a comparatively new development and will permit of carrying heavier current for the same conductor size than with standard V-C insulation because of its higher permissible operating temperature. They may be justified where hot locations are encountered or where there is a desire to carry heavy current without regard to voltage regulation.

Paper-insulated cables must have a lead sheath; consequently, there are some instances where these cables are at a disadvantage, especially in large single-conductor sizes carrying heavy currents. High sheath losses may result, and surrounding conditions may cause electrolysis or corrosion. Sheath losses can be reduced, however, and paper-insulated cables can be employed to good advantage when heavier current is to be carried and lead sheath is not objectionable; also, when the highest reliability and longest life are desired.

Composite asbestos and varnished-cambric insulated cables are selected when they must operate at unusually high copper temperature (above 85°C), usually because of a high ambient temperature.

All asbestos-insulated cables are able to withstand a maximum conductor temperature of 200°C, and are used for operation up to 600 volts when the temperature is unusually high. Both types require that moisture conditions be carefully watched.

For 601 to 7,500 volt operation, rubber, varnished-cambric and paper-insulated cables are all used, but greater discrimination is necessary in the selection of the proper insulation.

Rubber-insulated cables are used for a wide range of applications up to 5000 volts, especially with small and moderate-sized conductors. In this voltage range the use of special rubber compounds becomes more justified because of the advantages they offer, the relatively greater importance of reliability of the circuit, and the over-all economy in their use, despite their somewhat higher cost.

Composite asbestos and varnished-cambric cables are available up to 7500 volts.

Varnished-cambric insulated cables are, however, more widely used in this voltage range for the reasons given previously in the discussion of 600 volt operation, and for these additional reasons:

1. They can be used in dry locations with a braid covering instead of lead sheath, thus saving in weight, cost, and cable diameter.
2. Cables with varnished-cambric insulation are used in places where space or convenience does not permit the use of potheads. For indoor use where cables are free of moisture, the ends can be terminated by taping.

High temperature V-C insulated cables also are available in this voltage range.

Paper-insulated cables also are widely used in this voltage range for the same reasons enumerated under 600 volt operation. Where space is a factor, and hence the diameter of the cable is important, the smallest permissible cable size can be obtained with paper insulation, because insulation thickness is smallest by comparison with other kinds. Sector shape conductors can be used in multi-conductor cables and will further reduce the cable diameter. Paper-lead cables, however, require potheads, for voltages above 600. Below 600 volts, potheads can be omitted under some conditions, but that is not usually preferable.

For power circuits operating at 7501 to 15000 volts and above, rubber, varnished-cambric and paper-insulated cables all are used. Selection should be made only after careful consideration of the operating and installation conditions. Paper-insulated cables are excellent for this voltage range because for such circuits, usually main feeders, the combination of advantages offered is most suitable. Among them are: (1) highest reliability and longest life; (2) highest permissible conductor temperature, hence maximum conductor efficiency; (3) sector-shape conductors can be used in multiple-conductor cables; (4) minimum insulation thickness by comparison with other insulations; (5) where cable diameter is important, as when installed in ducts, a minimum overall cable diameter can be

obtained; (6) paper insulation affords the greatest uniformity and highest unit dielectric strength.

Varnished-cambric insulated cables likewise are excellent for this voltage range, as is well known by steel engineers. Their somewhat different advantages have already been set forth and their reliability is well known.

MAXIMUM PERMISSIBLE TEMPERATURE RISE

The maximum permissible temperature rise to which insulation can be subjected is shown in Figure 1. This temperature naturally limits the rise of the copper conductors and is important to you because temperature rise is the basic factor on which current-carrying capacity is determined.

It is important to remember that to operate a cable with a higher copper temperature than shown in this table simply means that it is being punished for doing more than intended and will result in much shorter life and less factor of safety than it would have if operated below these values.

The temperatures for paper-insulated cable are in accordance with practice approved by the Association of Edison Illuminating Companies; and those for varnished-cambric, rubber, and asbestos-insulated cables are in accordance with practice approved by the Insulated Power Cable Engineers Association.

Figure 2 shows how heat is dissipated from a cable in a duct structure and the three steps by which temperature rise is usually calculated.

SHIELDED OR NON-SHIELDED TYPE CABLES

A shielded type cable is one in which a grounded tape, usually a metallic tape, is placed immediately over the insulation around each conductor. A non-shielded type cable is one in which this shielding tape or grounded tape is omitted and, for three-conductor, usually consists of conductor insulation with a belt of insulation around all the cabled conductors.

Now why do you use a shielded-type cable and when? Because it has the advantage of better heat radiation which is reflected in a higher permissible operating temperature of the insulation, and the ability to carry more current. But just as important is the fact that shielded-type cable produces a uniform radial stress throughout the insulation and keeps non-insulating materials, such as filler material, outside the dielectric field. This all means that under certain conditions, a shielded-type cable is safer and provides the ability to carry more current than it would be if it were not shielded. For example, if you use a rubber-insulated non-leaded cable on a 6600 volt circuit, you would generally be safer by using a shielded-type cable. Or if you were installing a 15 Kv. cable for operation at 13,800 volts, shielded-type would be better because it offers greater strength in the insulation and is less liable to trouble. Another good reason for using shielded-type is that it provides greater safety against damage from switching surges and lightning. In the lower voltages such as 600 and 2300 volts, shielding is not so important and usually is not used because these cables do not have to be protected to the same extent that a higher voltage cable does and long experience has shown that a non-shielded type (belted) is entirely satisfactory.

DAILY LOAD CYCLE

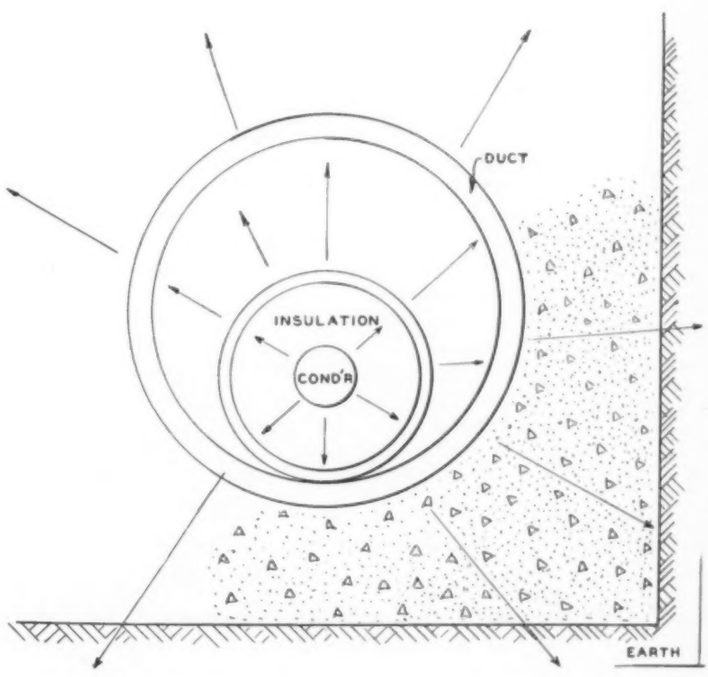
This item is also one of those that are important to you because it helps to determine the amount of heat loss which must be radiated from any cable or group of cables. The rate with which heat is radiated from the cable obviously is important because if it is not radiated as fast as it is generated, the temperature will build up and the cable eventually will fail.

It is important for cables in ducts and conduit but not for aerial cable. The shape of the load curve over 24 hours influences the temperature of the insulation, because it determines how much and how often cooling is permitted. Intermittent loads with intervals for cooling will raise the temperature a lesser amount than the same load carried continuously for the same aggregate time.

Daily load factor is derived by selecting a typical daily load curve and dividing the sum of the squares of the hourly current values by 24 times the square of the maximum current during the same period. If full load is practically continuous for 5 or 6 hours or more, that is sufficiently long to bring the cable to a steady maximum temperature condition and, for that reason, must be considered at 100% load factor.

There is a big difference between 100% load factor and 75% load factor, because in the latter case there is only 62½% of the heat to be dissipated. All this is reflected in the calculation for current-carrying capacity and shows up very decidedly in the final conductor size chosen and hence affects the size of cable, its cost and the size of ducts required. You may be using too large

FIGURE 2—The manner in which heat is dissipated from a cable in a duct structure and the three steps by which temperature rise is usually calculated.



or too small a conductor size if you have not used the right load factor.

SINGLE VS. MULTIPLE-CONDUCTOR CABLE

Before conductor sizes can be determined, a choice must be made between single or multiple-conductor cables since it has a direct bearing on the rate of heat dissipation and the important item of diameter, hence the area of the surface of the cable from which the heat must be radiated.

The choice of three single- or one three-conductor cable for three-phase circuits usually depends on economy, space available, convenience in keeping storeroom stocks, length of conduit run and other considerations. Sometimes the lower reactance of the three-conductor cable is a factor, thus providing better regulation. If the cables are lead sheathed or armored, the sheath and armor losses of single-conductor cables, especially for larger conductor sizes, must be taken into account, since they have a decided effect on current-carrying capacity. Sheath losses for three-conductor cables on balanced circuits are negligible.

The current-carrying capacity of three single-conductors in one duct is about the same as one three-conductor cable of equal conductor size; in separate non-magnetic ducts, about 35% to 50% greater.

TYPE OF SHEATH OR COVERING FOR POWER CABLES

When paper insulation is used, there is no choice in the matter but to employ a lead sheath. One of the many advantages of lead sheath is that it is absolutely permanent protection against the entrance of moisture and other ingredients that might be destructive to the insulation, such as acids, alkalis, solvents and others.

With V-C insulation, neither lead nor a jacket, but only a braid is necessary in dry places. In wet places, a lead sheath is preferable to a rubber jacket. If a rubber jacket must be used, that most commonly employed for V-C cables is the reinforced rubber jacket of the Navy type, and this is not usually recommended for other than just damp conditions.

On rubber-insulated power cables, rubber jackets of various types are furnished, including those for rough heavy work up to 6600 volts and higher. The 60% jacket is excellent for resistance to moisture and mechanical abrasion. Synthetic jackets are available, which are especially suitable for resistance to moisture, transformer, lubricating and other mineral oils. For 600 volt circuits, and sometimes higher voltages, rubber compounds are available, suitable both as insulating and jacket materials without any protective covering, unless it is needed for severe mechanical conditions. In this case, the insulation and jacket are one and the same, but the total thickness is increased somewhat to provide both insulation and jacket service.

CONDUCTOR SIZE

Now we come to the determination of conductor size and current-carrying capacity of the cable which is usually the final step in the design. Each of the items discussed above are necessary and important and must be decided before the calculation can be started for current-carrying capacity. This is one of the real fundamental problems of cable engineering, and perhaps the least understood.

As previously stated, conductor size is chosen principally for its fitness to these requirements:

1. Voltage regulation.
2. Permissible energy losses,
3. Current-carrying capacity.

First, a tentative size is selected, its impedance and then the voltage regulation of the circuit is calculated. It is then checked for permissible energy losses. If satisfactory, proceed to calculate its current-carrying capacity. If not, a larger size is chosen and the same procedure followed again.

For the amperes to be carried, the minimum size conductor should be selected to keep the temperature rise below a safe value for the insulation used. Thus it can very readily be seen that the selection of conductor size must be made with the insulation in mind. For example, a 3/c, 15 kv., paper-insulated non-shielded type cable would require a 4/0 Awg. conductor to transmit 186 amperes at 75% load factor, 9 loaded cables in a duct bank below ground, equal to 2200 kva., 3-phase at 6900 volts. This same conductor size when made up with varnished-cambric insulation and operated under the same conditions would carry only 144 amperes without overheating the cable. To obtain 186 amperes with V-C insulation, the conductor size would have to be 350,000 c.m.

After the tentative conductor size is selected, the physical dimensions of the cable can be found, and cable characteristics calculated.

For direct-current circuits, the selection of conductor size is much simpler. The regulation is easier to check since resistance only is required instead of impedance. The current-carrying capacity tables referred to do not include 600 volt insulation thickness, but the values for 5000 or 7500 volt insulation are approximately correct for lower a-c voltages. For d-c, correction factors varying from 1.005 to 1.115 for conductor sizes from 300,000 c.m. to 2,000,000 c.m. are applied to the values in the tables for 5000 or 7500 volts.

If the calculated conductor size is too large for convenience, twin or double circuits can be used, as is discussed later on.

Some mills have standardized on a few conductor sizes and carry spare lengths for emergency.

NATIONAL ELECTRIC CODE

There is some tendency to use the National Electric Code for selection of conductor size. It should be pointed out emphatically that even for 600 volts and below, such practice may be misleading. Figures given in the Code for sizes of conduits and conductors are the minimum, for safety only. These figures give no consideration to voltage regulation and the length of the circuit, nor energy losses. For voltages above 600, they do not apply at all and their use also would be misleading, even for allowable current.

It is far safer to use the tables already mentioned for allowable current. These have been approved by the Edison Electric Institute and Insulated Power Cable

Engineers Association, and are correct for the cable constructions and installations stated therein.

We now come to the discussion of some other general factors of design applying to all types of cables and more than one kind of insulation. These include the items mentioned above consisting of making proper provisions for the conditions under which the cable is installed and for adequate protection of the insulation.

SINGLE VERSUS DOUBLE CIRCUIT

This paragraph refers to the question as to whether in some cases it is preferable to install double circuits for any one three-phase circuit in place of a single circuit; that is, 6 single-conductor cables instead of 3, or two 3-conductor cables instead of one. In some cases, the question may be as to whether one should use very large single conductor cables or several 3-conductor cables. The answer usually is found in the consideration of these items:

Economical size of single-conductor cable and of three-conductor cables

Size of conduit available, or economical size of conduit necessary

Convenience in handling cables during installation

Maximum standard size adopted for your mill, and other items

Single-conductor cables, in sizes above 1,000,000 c.m., often become too unwieldy to use under many ordinary conditions, especially if conduits or ducts or other space available has already been installed. Cables as high as 3,000,000 c.m. to 5,000,000 c.m. are made and can be installed, but require installation conditions satisfactory to their larger diameters, such as large radius bends. The skin-effect and proximity-effect of these larger cables (i.e., a-c resistance) becomes appreciable with a consequent reduction in current-carrying capacity, and, therefore, a certain economic loss is sustained in the use of copper unless they are annular conductors. It is better, therefore, to use the latter if space is available, in sizes of approximately 2,000,000 c.m. and above because of their much smaller increase in a-c resistance over d-c resistance. Large size single-conductor cables also are rather stiff. If the plant standards have set upon a certain maximum size of conductor, it becomes reasonable to divide the circuit into six or more conductors, and install them in smaller conduits. At the same time, a certain flexibility in circuits is obtained when changes in circuit load occur later on.

Advantages in favor of six single-conductors instead of three are: Ease of handling, convenience in making future circuit changes, improved regulation. For example, three 1,000,000 c.m. cables, spaced closely together in a triangle, carrying 600 amperes a distance of 500 ft., will have a drop of 15.0 volts. Six 500,000 c.m. cables in close hexagonal configuration, carrying the same load the same distance, will have a drop of 9.0 volts when arranged as indicated. This difference is due to the difference in reactance, resulting in a reduction of 40%. The resistance is the same in both cases, since the circular mil area is the same. See Figure 3.

CHOICE OF CABLES WITH OR WITHOUT BRAIDS

Braid coverings usually are used only for varnished-cambric or rubber-insulated cables, or for all kinds of insulated cables where the braid is part of the outside protective covering for aerial or direct earth burial.

CONTROL CABLE

In the case of rubber or V-C insulated control cables located in dry places, the use of an outside braid is principally for mechanical protection, moisture and flame resistance. One or two saturated braids are employed, as may be necessary. Individual braids around the conductors also are used to provide a means of color indentification which is available up to 81 conductors per cable. If the braid is omitted, partial identification can be accomplished by ridging the insulation of one conductor in each layer of the cable.

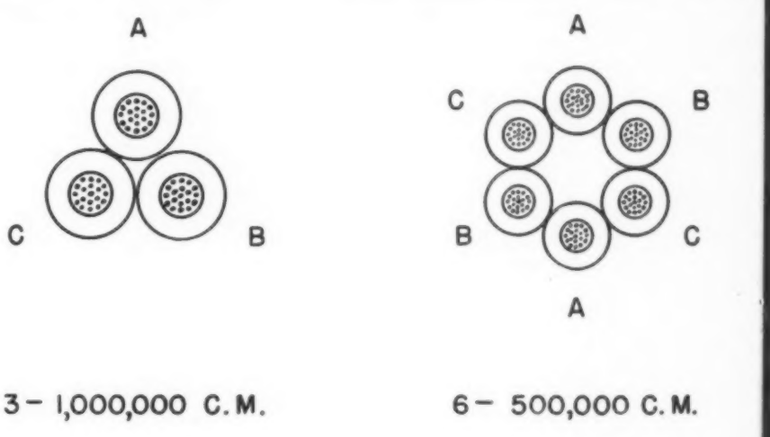


FIGURE 3—Single versus double circuit.

The specifications of many of the large railroads in this country permit of the use of rubber-insulated control cables without a braid over the individual conductor. The manufacturers have no choice and are continually making them in quantity with or without braid.

POWER CABLE

One or two braids over rubber-insulated cables, especially single-conductor, are also employed for their mechanical protection, moisture and flame resistance. Several types of saturant are available. Jackets are available made of high rubber-content compounds, and they are highly resistant to mechanical damage without any braid or other protection. In these cases, the braids can be omitted, but if so, it is extremely undesirable to pull plain rubber sheathed cable over rough surfaces where sharp points may protrude, since, rubber when wet, cuts very easily when drawn over sharp

edges, and the jacket or insulation may be destroyed.

LEAD SHEATH VERSUS RUBBER JACKETS FOR CONTROL CABLES

There appears to be some difference of opinion as to whether lead sheath or rubber jacket is preferable on control cables. The authors have no desire to take any side, but merely to point out some of the advantages and disadvantages of both constructions.

The question is not so much whether one or the other is better, or what has been successful in another plant, but rather, which one fits your conditions best. You would not select a circuit breaker until you were sure of all the details of what you wanted in it. The same is true of control and power cable sheaths. Learn what conditions you must meet, then select the right construction.

The usual insulation for control cables is rubber; occasionally varnished-cambric. In the latter case, it would be good practice to use lead sheath in preference to anything else, whether the cables are placed in conduits or racks, wet or dry.

As to rubber insulation, there are available now in the industry, several grades of compound, all of which are very satisfactory for control cable insulation. Some of these are known for their improved resistance to moisture.

LOW MOISTURE ABSORPTION

A good deal of emphasis has been placed recently on low moisture absorption. This is an excellent characteristic and several manufacturers are making one or more such compounds. Low moisture absorption is important in control cable circuits carrying small currents because of the necessity of maintaining high insulation resistance. On all other ordinary control circuits it should not be over-rated to the detriment of other characteristics equally important; such as long aging and resistance to service exposures other than moisture, all of which tends to give you uninterrupted service.

Figure 4 shows briefly a comparison between the use of lead and jackets. The choices shown, however, should not be taken as recommendations until all exposures and conditions are considered in combination. These are many and could include alkaline solutions, acid solutions, oily water, oil and high temperature, etc. Such solutions should be analyzed beforehand, if possible, so you will know what will be encountered.

As long as rubber-insulated control cables are located in dry or just mildly damp places, neither lead nor rubber jacket appears to be necessary, merely a rubber-filled tape and braid covering. Where they are subject to considerable moisture or to submersion such as during floods, either lead sheath or rubber jacket is successful. Careful manufacture and methods of installation must be followed to insure the integrity of either one. Rubber jackets are subject to the danger of cutting and they also have the disadvantage of being subject to deterioration from the presence of acids, oils, solvents, and other materials not ordinarily affecting lead sheath. But when the proper compound is selected, successful operation is more assured and these troubles are minimized. For example, in several cities, there are millions of feet of 600 volt rubber-insulated cables on low voltage circuits, installed without lead sheath, much of it submerged in water with the rise and fall of the tide. Their operating record has been perfect.

At the same time, lead sheath should, by no means, be discarded because of some trouble you may have encountered with electrolysis and corrosion. Lead sometimes gets the blame for troubles that are not its fault. One common source of trouble is corrosion from water seeping through conduit joints; another is that conduits are not properly drained; a third is that the sheaths are not properly grounded and bonded. These points are discussed later. The point to all this is: Don't blame all your troubles on lead sheath; maybe they have come from construction difficulties; perhaps they can be cured by changes in your operating practices. Lead sheath has been used successfully in great quantities for many years by the power companies. New York City streets contain thousands of miles of lead-sheathed cables operated by at least twelve different companies, where electrolysis conditions would be terrible if they weren't under control. Get all the facts together, then decide.

FLOOD CONDITIONS

Some steel engineers prefer to use an insulating compound on the conductors which will be highly resistant to these other deteriorating materials as well as to moisture, and depend on the insulation itself without any additional protection, other than for mechanical reasons. This speaks very well for the improvements made by the cable manufacturers in providing such

FIGURE 4—Protective covers for control cable installed indoors. (Partial list)

Exposures	Tape and Braid	Lead Sheath Plain or Alloy	Jackets Rubber or Synthetic Plain or Braided
Always dry	1		
Occasional Moisture	1		
Damp or wet		1	2w
Acids, alkalis		2	1
Solvents		1	2s
Mineral Oils		1	2s
External heat		1	1a or w
Vibration			1r
Electrolysis		fibrous coverings, suitably saturated and finished with moisture-resisting compounds	non-metallic sheath depending on other exposures

NOTE: Numbers refer to 1st or 2nd choice.
r = rubber jacket
w = rubber and woven cover jacket
s = synthetic jacket
a = asbestos braid
These constructions should not be followed as recommendations until all the exposures involved are considered in combination.

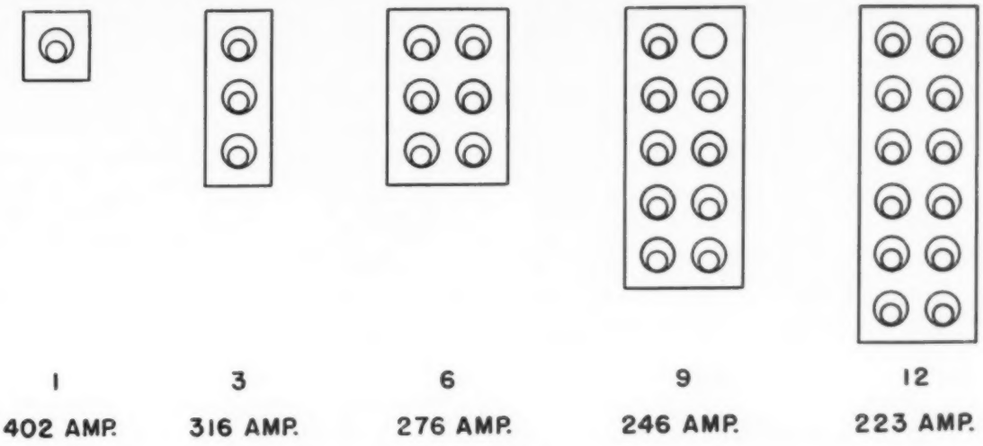


FIGURE 5—Maximum current rating in duct banks in earth for a 3/c 500 mcm., 15 kv, paper insulated non-shielded type lead covered cable. 20°C. ambient, 100% load factor. All cables similarly loaded.

high grade rubber insulation, but it seems to deserve the remark that over an extended period of time, there are possibilities of other destructive ingredients attacking the insulation and considerably shortening its life with attendant risk of interruption to production.

Under flood conditions, one point of vulnerability to both jacketed or lead sheathed control cables appears to be the ends of the cable. If they are submerged, water may readily flow down the strands inside the insulation and along other parts of the cable inside and outside the sheath. This is a rather severe service for any insulation, but, from studies that have been made, it would appear to be possible to provide against that emergency by protecting the ends of the cable against the entrance of moisture either into it or the conduit.

RECOMMENDED MINIMUM BENDING RADIUS

Cable Description	Minimum Radius Multiply by Overall Diameter of Cable (Inches)	
Paper:		
0 to 20,000 volts	8	
20,001 volts and higher	10	
Varnished-Cambric:		
0 to 10,000 volts	5½	
10,001 volts and higher	7	
	Up to 500,000 c.m.	500,000 c.m. and over
Rubber:		
Up to 8/64″ insulation	3	4
9/64″ to 12/64″	4	5
13/64″ to 20/64″	5	6
21/64″ and over	6	6

2. INSTALLATION

Improper cable installation will reduce dependability and life in the same way as improper design. The following discussion concerns some of the more important factors and their relation to selection of cable.

MINIMUM BENDING RADIUS

Below are given the minimum bending radii (not diameter) for paper, V-C and rubber-insulated cables as recommended by I.P.C.E.A. for permanent installations. In any installation, the radius of the bend should be no smaller than these. The drum diameter of shipping reels is always equal to or greater than twice these radii.

DESIGN AND RATING OF DUCT BANKS

This refers particularly to duct banks in the earth. Greatest heat radiation, hence greatest efficiency, can be obtained by designing the duct bank so that all the ducts are on the outside layer; that is, a maximum of two ducts wide. If control or any low heat-producing cables are included in duct runs, the duct bank can be made wider or higher, and the control cables placed in the inside layers, provided the insulation on the individual conductors of the control cable is selected to withstand the temperatures to be encountered in these inner ducts. This is an important point.

The usual question that arises with duct bank is how they affect current-carrying capacity of cables.

Figure 5 shows the reduction in allowable current in a cable for groups of one to twelve cables in a duct bank, the same cable in every case and all similarly loaded. The reduction in allowable current as you know, is due to increased heat to be dissipated from the available duct bank area. Referring to the figure, it follows that for a given amount of current, say 1200 amperes, 4 cables must be employed instead of three, in one duct bank.

Figure 6 shows a 9 x 6 duct bank, an example of poorer construction, since the heat dissipation from the inner layers would reduce the allowable current from 100% on the outer layer to 74.4% in the second layer

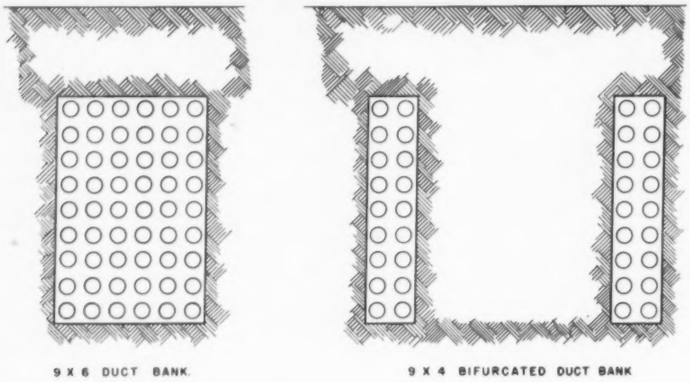


FIGURE 6—Examples of duct bank construction.

and 65.5% in the third layer, as computed from an actual case with all ducts loaded. If all the ducts are not loaded, there is still some reduction in the inner layers.

The bifurcated duct bank is an example of good construction when a large number of cables are to be carried by the same route. All the cables are in outside ducts where heat radiation is a maximum and the cables are in good position for training in manholes. Good design usually requires a separation of 4 feet or more between adjacent faces of the two halves.

CONDUIT CONSTRUCTION

Conduit should always be installed with a slope to allow drainage throughout the entire run.

In laying out fibre duct lines in concrete, the conduits should be so placed that they are separated not less than 1½" between the outside surfaces of adjacent conduits. In laying the conduits, all joints should be staggered at least 6 inches both vertically and horizontally.

Fiber conduit is made of a tubular section of wood-pulp fibre treated and impregnated with a bituminous compound and produces a structure that is weather resistant, insulating and preservarive in nature. If, therefore, the joints are constructed so as to be tight, the entrance of moisture seeping through the concrete will be eliminated.

To insure tight joints, it is customary to paint the ends of the fiber or the inside surface of the coupling with an asphaltic paint before joining the individual sections. When the socket-type joint is used, an alternate method is to dip the recessed end of the fiber to a depth of about ¼" into a bucket of hot tar. Some specifications require the wrapping of muslin tape over the joints and painting of the tapes with asphaltum compound.

It is very important to swab out all ducts and conduits before pulling in any wire or cable. This tells you whether they are clean and dry.

PREVENTION OF CORROSION

Most steel mills contain many thousands of feet of steel conduit embedded in the concrete of the floors, and foundations. Since the concrete is porous, ordinary screwed conduit joints cannot completely be depended upon for the exclusion of water. If loose joints are permitted, water seeping through the concrete, especially green concrete, will pick up lime and become a lime water solution of such a concentration as to be highly corrosive to lead. Its presence should be avoided. This action has been known to occur in other places, with the result that sheath corrosion has occurred and the blame placed upon the sheath, rather than on the conduit installation.

Such troubles can be minimized or eliminated in two or three ways. One is to make welded joints. Another is to make a good tight screwed joint in each case, possibly using pipe-joint compound where moisture is severe, followed by a generous smearing of an asphaltic type of sealing compound around the outside of the joint. One steel company just recently changed to this practice for all conduit joints in concrete. Another method is to use copper or copper alloy conduit with soldered joints. As you know, such conduit is available with all the necessary fittings.

On existing installations where corrosion may be in process, and the ducts are well drained, it can be arrested by flushing the ducts with a weak neutralizing solution. When not well drained, the very successful method of one company was to pump the ducts full with a cheap grease, effectually blocking off any more water flow.

When it is impractical to keep the ducts dry, it is common practice to apply fibrous coverings suitably saturated and finished with moisture-resisting compounds over the lead sheath.

PULL BOXES VERSUS MANHOLES

In general, it can be said that manholes are necessary principally when large size and high voltage power cables are to be jointed, where the duct runs are below ground, and where the installation requires protection against danger to human life by enclosing all the cables within concrete or brick walls.

Many advantages will be gained from the proper drainage of manholes. They should always be built at least 6 ft. high, so that a man can stand up in them without bending over. Manholes are convenient places for the location of subway transformers for power and lighting service when such locations are convenient to the load.

When it comes to the routing of smaller size and lower voltage power and control cables above the lowest level, and where there are a large number of them to be routed in several directions, pull boxes become highly advantageous as a means for effecting convenient points at which to pull the cables through the conduits, limit the length of runs, route cables into the next conduit run, and make joints. They also require less work during the layout period, because it is not absolutely necessary to trace out the complete route of every cable run from beginning to end, since cables can be crossed in the pull-boxes without trouble.

When pull-boxes are placed vertically in the walls or foundations, the covers of the pull-boxes become a convenient place for the location of light-weight apparatus equipment and thus save floor space often needed for other things.

3. OPERATION

This section is limited for lack of space. We have already discussed how cables should be protected against external heat and that the hottest point determines the current-carrying capacity of the whole run.

One of the most important factors in operating lead-sheathed cables is that of sheath grounding and bonding, both because of protection against cable damage and loss of production, and against human life. If you are not sure your cables are properly protected this way, they should be surveyed and corrective steps taken. Survey procedure is well established.

CABLE SHEATH GROUNDING AND BONDING

Cable sheath grounding and bonding is generally recognized as good practice. Its purposes are several. One is to protect the sheath from damage due to excess current during the passage of fault current through the sheath or in the event of a short circuit to ground. Another reason is to provide assurance that sufficient current will flow to ground during a fault to give positive action to protective relays or to give definite indication to the station operator that an abnormal condition exists at some point on the system. Another is electrolysis mitigation. Bonding together of several cable sheaths in any duct bank provides a much lower sheath resistance than if there were no bonding; also the current flow through the relatively high resistance of a single lead sheath might easily be limited to a value of the same order of magnitude as the normal current. This might result in an arc at the point of fault which would persist for a relatively long time with possible disastrous consequences to the cable sheath.

Bonding also serves to minimize the effects of electrolytic action by stray currents from electric railway circuits and other d-c sources. Grounding and bonding also help to maintain the lead sheaths at practically ground potential and eliminate the danger to workmen's lives in the event of contact during a severe short circuit. Under normal conditions, with practically the same current flow in all three conductors, the induced sheath voltage is negligible. Under short-circuit conditions, with a relatively high current flowing in one conductor, dangerously high sheath voltages may be induced unless the sheaths are properly bonded and grounded.

Two general methods of bonding are in use. One of these consists of soldering the bonding wire to all the lead sheaths in any manhole or group of cables proceeding with the bonding wire from one sheath to the next, thus forming a loop. The other is to bond a wire to each sheath and in turn solder this wire to a bonding bus. Another variation of this latter method is to clamp a wide strap, say ½ inch minimum, to the lead sheath, and in turn solder the strap to the bonding bus. This latter method is looked upon with favor by some engineers, since it eliminates the presence of solder in contact with the sheath and thus may possibly prevent corrosion later on.

The bonding bus should be of ample size and preferably of strap copper, approximately ⅛″ or ¼″ thick by 1″ or 1½″ wide, which can be attached to the side walls of the manhole at a convenient point and carried down to a ground rod or neutral wire in the duct, if such is used. All bonds, bonding buses and leads should be tinned.

It is most essential that any bonding system, to be effective, must be properly soldered or clamped and must be done with care and thorough workmanship. Care should be taken not to injure the lead of the sheath or the joint during bonding. In any method of bonding, loose tape lying against the sheath should be avoided. Where such has been overlooked, electrolysis between copper and lead may take place.

Grounding at the manholes or other places can be accomplished by ground rods or by a neutral bus. It is the practice of some companies to run a neutral bus the entire length of the duct system. It consists of a 4/0 Awg. or larger 7-strand soft tinned copper cable. The cable sheaths are bonded together and connected to the bus. All the hardware in the manholes should be bonded and connected to this neutral bus or the ground rods. All grounds should preferably be a minimum and of the same potential above earth potential.

CABLE VERSUS BUS FOR HIGH CURRENTS

This subject is somewhat aside from the main topic of discussion, but is included because steel men often are confronted with the decision as to whether cable should be selected in some cases, rather than bus.

When properly constructed, either bus or cable is entirely dependable. The first requirement of a bus is that it shall be located in a protected place, free from moisture and mechanical interference. Bus insulation of porcelain, micarta, ebony-asbestos or similar material can be installed so that it has a high factor of safety which readily can be increased, if desired, at only a small increase in cost. In addition to bus requiring a protected location, there is the necessity for a considerable amount of space, especially for multiple circuits, but if the space is otherwise unused, this disadvantage becomes rather small.

The advantage of a bus installation is that it is relatively permanent and is not subjected to the same deteriorating influences as in cables such as ionization, possible inclusion of moisture and comparatively high dielectric stress on the insulation.

Standard concentric stranded conductors are made and insulated up to 5,000,000 circular mils, as shown in Figure 1. Annular conductor cables also are made up to 5,000,000 c.m., the current-carrying capacity of both depending on the usual governing conditions previously discussed. The annular type has better current-carrying capacity because of its greater diameter and more efficient use of the copper area.

It is difficult to establish a definite value of current beyond which bus should be used instead of cable, because the entire installation depends upon so many other items. It is probably safe to say, however, that when installation conditions are favorable to a bus, it would be advisable to consider its use when the

current to be transmitted is greater than 1,000 to 2,000 amperes.

Choice of bus shapes can be made among flat bar, standard pipe size and extra-heavy copper tubing, channels and angles. In general, below 1,000 amperes, flat bar may prove to be the most economical. Above 1,000 amperes, channel or angle may prove the more economical. Angles have somewhat better heat dissipation characteristics than channels, hence, with proper ventilation, angle bus would run a little cooler or conversely, a slightly smaller cross-section could be used. Channels and angles always have better mechanical strength than bars against short circuit stresses. Tubing is used more frequently for special cases, such as central station or sub-station buses.

The choice of shapes for the bus must be considered largely from mechanical consideration as well as the amount of current to be carried.

Such items are:

1. Length of run
2. Number of taps
3. Distance between supports
4. Short circuit stresses
5. Space available

They must be properly weighed before the decision is reached as to what should be used. It is quite possible to run the cost of fittings to as much as four times the minimum necessary if the designer lacks familiarity with fittings and fitting costs. In addition, installation costs vary somewhat in accordance with the shape of conductor selected.

In conclusion, let us emphasize briefly some of the points brought out in this paper.

1. Select cables of balanced design.
2. Proper and careful methods of installation and operation will prevent trouble and loss.
3. Choice of conductor size is based on voltage regulation, permissible energy losses and current-carrying capacity.
4. Current-carrying capacity of a cable is based on temperature rise and involves many factors, all of which should be considered.
5. Current-carrying capacity is affected by the kind of insulation used.
6. Lead-sheath or jackets for cables should be selected to fit operating requirements.
7. Duct runs, if not properly designed, will reduce the capacity of the cables therein.
8. Cable sheath grounding and bonding should be carried out according to good practice.
9. Greater dependability will be achieved by attention to all these factors.

DISCUSSION

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T. B. McELRAY: I was fortunate to have received a copy of the paper presented by Mr. Rosch, Mr. Aime, and Mr. Steinmetz at our Chicago Convention, and have read it in its entirety. I believe it is one of the outstanding papers that have been introduced since my connection with the Association of Iron and Steel Engineers. It will be a wonderful reference volume for all of us to have in our own office. I have already referred to it several times since I have had it in my possession, and have checked some of the data which it contains against an installation that we have had in operation for a long time with heavy 220 volt currents, and found the data to be 100 per cent correct. We rearranged this circuit accordingly with greatly improved results.

E. W. DAVIS: The authors of this paper are to be congratulated on the thoroughness and completeness of their discussion of the factors which influence the selection and design of insulated cables for steel mills. This paper should be found in the data files of every electrical engineer who is engaged in the construction, operation, or maintenance not only of steel mills, but of any mill or factory engaged in the production of manufactured products.

This short discussion of the authors paper is not intended to detract in any way from the credit due them for a most excellent presentation. This discussion is intended only for emphasis of one or two factors which appear to some experienced engineers to be of most importance.

The impression one receives from a study of the paper is that for power circuits in moist or wet ducts and locations, lead covered cables only are recommended to prevent moisture absorption by the cable insulating materials. Only for control circuits, are rubber jackets occasionally recommended for moisture protection. The only reference to rubber insulation having low moisture absorption characteristics is for control cables, and there the reader is cautioned not

to "over rate" moisture absorption to the "detriment of other characteristics equally important".

We believe that this inference of limitation of the use of low moisture absorption rubber insulation to control circuits most unfortunate, and the cautionary note regarding "other characteristics" of low water absorption rubber insulation most misleading.

Experience in many of your steel mills has proved beyond much doubt that lead sheaths on control and power cables are far from permanent and that cables protected by lead sheaths do not always give uninterrupted service. Examination of cables that have failed show broken and split sheaths, and these breaks or splits are generally caused by damage during installation, electrolysis, stray a-c currents, corrosion, or vibration.

Water or moisture enters the cable through the sheath breaks and soon cable failure occurs due to the gradual but nevertheless sure absorption of moisture by the conductor insulation, regardless of whether that insulation is paper, varnished cambric, or ordinary rubber compounds not specifically designed to resist moisture absorption. The only difference between the cable failure is one of time, the paper insulated cable failing within a few hours or days, the varnished cambric insulated cable failing within a few days or weeks, and the rubber insulated cable failing within a few weeks or months.

Modern design of cables for service in wet ducts or locations demands the use of rubber insulation which is not affected by moisture or water, and this applies to power cables as well as control or signal cables. By so doing, lead sheaths or other mechanical moisture protectors are eliminated, and the cable cost often greatly reduced, with the positive assurance of long uninterrupted service.

Rubber compounds are now on the market that have extremely low water absorption characteristics, and at the same time have equal and often better physical and electrical characteristics than similar compounds not suitable for wet service. For instance, when compared with standard 30 per cent compounds of the A.S.T.M. Type, Class AO, low water absorption compounds are available having approximately one-half the specific inductive capacity of the older type (very important in signal and control cables), 50 per cent higher dielectric strength (very important for power cables), and 1000 per cent longer life when exposed directly to moisture or water. A superaging long life-rubber insulation is available having all the physical and electrical characteristics of the best of such compounds, yet having such low water absorption characteristics as to assure the 1000 per cent longer life than could be expected with such compounds not specifically designed for wet service.

The development of low water absorption rubber insulation is one of the most important steps in the progress of the use of rubber compounds on wires and cable.

Obviously, the first step toward the control or elimination of water absorption was a thorough, systematic study of the phenomenon itself. This involved the determination of rates of absorption under varying conditions by different types of rubber compounds, the effect of temperature, the influence of materials dissolved in the water and the ultimate effect of these factors on the electrical properties and submerged life of the insulating material.

Research in the Simplex laboratories determined conclusively that moisture absorption of rubber compounds is traceable to the proteins in the rubber, and resulted in the development of rubber compounds made with deproteinized rubber. Compounds so made show extremely high resistance to intermittent or continuous exposure to acids, alkalies, or their vapors, and the greatest resistance to water absorption of any rubber compounds obtainable today.

For many years, Gutta Percha was employed exclusively in submarine cables where the use of protecting lead sheaths was impracticable and permanence of electrical characteristics is of prime importance. Today rubber insulating compounds are available which have many times the resistance to moisture absorption of Gutta Percha, that have equal if not greater permanence of electrical characteristics when exposed to water, and which have the high dielectric strength, low power factor, and long aging properties so essential to power cables.

The use of low water absorption rubber insulation on non-leaded control and power cables has several very important advantages for steel mill engineers. A few such advantages are listed as follows:

(1) Reduction in initial cable and installation cost as compared to lead sheathed rubber insulated cables of the standard type.

(2) Reduction in installation costs because of simplified jointing procedure, elimination of bonding and grounding systems to control electrolysis and stray currents.

(3) Permanence—high electrical properties together with positive resistance to water absorption if and when water gets into the cable.

(4) Reduction in upkeep and replacement costs—eliminates the maintenance costs traceable in lead-sheathed cables to electrolysis, corrosion, crystallization and sheath currents.

(5) Uninterrupted, efficient service even under flood conditions.

A careful study of non-leaded cables insulated with low water absorption rubber insulation, is recommended to you.

F. L. Aime: The main consideration should be to analyze the problem carefully and select the cable which fits your conditions best. It is hardly practical to find any one construction which will fit all conditions best, any more than it can be said that you would select a circuit breaker of one design and size for all your circuits in the plant.

The IPCEA is preparing a bulletin containing a long list of recommendations for shielding. This will be available at some future date. At present, no standard recommendations exist. Briefly, our present recommendations are, in general, for any insulation:

(a) When greater safety is wanted against lightning and switching surges.

(b) When greater current-carrying capacity is wanted for any given conductor size.

(c) For protection of authorized or unauthorized persons who might come in contact.

(d) When protection is wanted for braided, non-leaded cables not on insulators.

(e) Where static discharge from braided, non-leaded cables, may be dangerous.

Comparatively pure lead is subject to inter-crystalline fracture from fatigue, when subjected to vibration. These are called fatigue cracks. The customary procedure is to add other elements to the lead to make an alloy. Cable manufacturers recommend tin. In other cases, antimony and calcium is recommended. This raises the fatigue strength of the metal, which in turn delays or prevents fracture. Experience has shown that in most service cases, the vibration stress is below the fatigue limit of the alloy, whereas it is above the fatigue limit of the pure lead.

MEMBER: I think this is a very valuable paper for reference, particularly so since it appears to me that, considering the important part which cables play in construction work in our plants, we give the subject very little study compared to what we ought to do.

There is one other thought which occurs to me at this time, namely, the fact that the thing begins to get so complex; we see so many ramifications of it going this way and that way. For instance, it occurred to me that there is a distinct possibility that you should consider the type of cable you are going to use even before you start to lay out a plan. Then there are other factors to be considered as to the accuracy and dependability of relay operation of underground vaults. If we employ shielded cable, what effect does this return have on the body with reference to ground currents? How does that influence your system of relaying and layout of the plant selection of cables should that be considered?

F. L. AIME: There is a difference in current-carrying capacity due to greater allowable temperature drop, and the better heat dissipation characteristics of the cable, which in turn is due to the presence of the shielding tape around the individual conductors. For example, a 3/c 15-kv belted-type paper cable has a maximum permissible copper temperature of 75 degrees C., whereas a 3/c 15-kv shielded-type cable has a maximum permissible copper temperature of 81 degrees C. The average increase in current-carrying capacity, for example, of 15-kv shielded cables over non-shielded cables is approximately 10 per cent, but this increase decreases slightly with the larger size conductors, as follows:

4/0—11.5 per cent increase over non-shielded.
350—10.7 per cent increase over non-shielded.
500— 9.5 per cent increase over non-shielded.
750— 8.0 per cent increase over non-shielded.

based on: 6 loaded cables per duct bank, 20 degrees C. ambient, and 75 per cent load factor.

The big advantage of shielded cables in relay operation is that it makes the majority of faults from conductor to ground. In addition, there is a definite metallic path for fault current to ground through the shielding tape. In the case of non-shielded cables, of course, the only path for the fault current is the lead sheath, when such is present, which is outside the belt, therefore requiring the belt to fail before the fault current can be established.

E. C. MARSHALL: It is one thing to have knowledge and make personal use of it, but it is greater to have knowledge combined with the will and ability to display it in such a way, that others may use it for the general benefit of industry.

The authors of this paper have done a very commendable thing for this Society in their very comprehensive contribution to it, and it is suggested that the scope of the treatise be extended, either by discussion, or a supplemental article, to incorporate data pertaining to design and methods of constructing duct lines, in which the cables are to be installed, including data on the pulling and splicing of cables, also reel data.

Considerable information has been published heretofore, but this paper appeals in its logical reasoning as to why specific recommendations are made in cable selections, thus serving the engineer as a good reference.

There are however, several items on which I would appreciate further emphasis and enlightment, and enumerate them as follows:

1. Under the caption "Current-Carrying Capacity", paragraph III:

> "It is important to remember that the hottest part of the cable run is the one which determines the maximum current carrying capacity of the entire cable".

Presumably, the authors refer to a uniform size throughout the entire run, whereas in practice, where the 40 degree C. temperature exists the cross sectional area of the cable could be increased or some cooling medium introduced to compensate for the higher temperature in possibly a small section of the entire run.

2. Reference was made by the authors about certain dislikes of the grounded system "because the failure of one leg grounds it, causes a short circuit and stops operation", but with modern differential protective relay equipment, the operation delays and damages are very probably less disastrous than would result from two phase short circuits from grounds on both phases as the result of one grounded phase being neglected.

3. What means would the authors recommend for determining the earth or ambient temperature in either an old or new duct run? Is there some device better than the thermocouple and pyrometer?

4. In speaking of "kind of insulation" reference is made to high temperature V-C insulation, a new development, about which further enlightment is requested.

What is meant by high temperature?

How much heavier current can be carried by its use?

What are the cable voltage limitations of its use?

Is the permissible increased current carrying capacity equivalent to the differential between ordinary V-C and P-I lead covered cables?

5. The use of lead covered cables in preference to braided and non-braided rubber cables may be slightly more expensive and conservative, but the practice is the result of many costly experiences, and the comparative success of the substitution is believed warranted. The uncertainty of the volumes of water about the mill whether from cooling sprays, roll necks or backed up from drains clogged with scale and the

extent of the pollution from oils, greases, and other ingredients, have necessitated protection to the underground electrical conductors and the performance of lead sheath has been both successful and satisfactory. Possibly the more recently developed synthetic jackets will meet the mill cable requirements, but from past experiences it is quite probable that many steel mill electrical men will have to be convinced by trial rather than by laboratory reports.

6. The remarks regarding single versus multiple cables for large currents also have some bearing upon the voltage selection for if too many and too large cables are required, it is possible the voltage selection was too low.

7. Regarding control cable the use of varigated colored braids over each conductor has been of very material aid in the original installation, of the modern complicated control boards, and invaluable at times of remedying troubled circuits quickly.

8. Referring to the design and rating of duct banks, it has been found that a substantial increase in permissible capacity may be obtained by incorporating within the line structure tile ducts approximately 8 inches by 8 inches cross section, in such a manner, that all cable ducts are on an outside layer and using the tile ducts for natural draft created by stand pipes or artificial draft utilizing some of the filtered air made available in the substations and motor room to which the duct lines are connected.

S. J. ROSCH: As stated in the paper, temperature has everything to do with current-carrying capacity, due to the fact that the process of getting the heat out from the conductor through the insulation and coverings to the earth or air, always results in a temperature drop—and it must be dissipated or the cable eventually would fail. The greater the allowable temperature drop, the greater the current capacity. If we use the six 3/c 4/O V-C cables mentioned previously in the paper, as a further example, we find their capacity varies with allowable temperature drop as follows:

Ambient	Total Allowable Temperature Range	Allowable Amperes Per Conductor Per Cable
10	50	213
20	40	187
30	30	155
40	20	116
50	10	50

Any hot spot, such as steam pipes, furnaces, cables outdoors in summer, etc., determines the ambient temperature, hence the total allowable temperature drop for the entire cable run, unless the length of cable at the hot spot is made with a larger conductor. In that case, the balance of the run is calculated as usual.

Ordinary V-C permits of a copper temperature of 75-E degrees C., and heat resisting V-C permits of 90-E degrees C. (maximum 85) for belted-type cables, where E equals phase to phase voltage, three phase. In single conductor and multi-conductor shielded-type cables, the permissible temperatures are $75\text{-}E/\sqrt{3}$ and $90\text{-}E/\sqrt{3}$ degrees C. (maximum 85) for ordinary and heat resisting V-C respectively. Heat resisting V-C thus allows greater current-carrying capacity for the same conductor size; or is very useful in hot locations having a higher than normal ambient temperature, so that conductor size in such places can be kept smaller than when ordinary V-C is used.

There is no standard accepted recommendation for maximum pulling strength of cables. The following rule is suggested by some cable manufacturers for leaded cables: Use a maximum pull of 10,000 lbs. per square inch of conductor area less 10 per cent for stranded conductors, and 10 per cent for cabling. This means that a 3/c stranded cable would be good for 8,000 lbs. maximum per square inch, and a 1/c stranded cable for 9,000 lbs. maximum per square inch. The National Electric Light Association recommends a maximum pull of 10,000 lbs. for 3/c cables of 350,000 c.m. and larger, and 1,000 ft. maximum length. Another method, considered a conservative one, has been to allow a pulling tension of 0.75 times the total weight of the cable being pulled. Under no condition should the stress be great enough to produce permanent elongation of the copper conductors.

For braided cables, the same rules apply in general, but in our opinion, these maximums should be reduced somewhat, depending on the conditions under which the braided cables are to be pulled, such as long lengths, number of bends, etc. Greatest safety and maximum pulling strength will be attained by the use of pulling eyes on leaded cables. On braided cables and rubber jacketed cables, the pulling should be done entirely with the pulling rope attached to all the conductors, with the leading end of the braid or tapes or jacket covered with tape so as to prevent it from dragging in the conduit. Small sizes of cable which do not have much weight, such as control cables, can usually be pulled safely by the use of pulling grips, unless the pulling friction due to the number of bends, etc., is high. In the latter case, the conductors should be tied in with the grips so as to distribute the pull between the conductors and the cable covering.

A 16 duct bank could be constructed 2 wide by 8 high, or if desired, a bifurcated bank, each section 2 wide by 4 high. A 20 duct bank could be constructed in the same manner, 2 wide by 10 high, but this would be an unusually high bank and therefore rather expensive, and it probably would be equally good to use a bifurcated bank, each section 2 wide by 5 high. We have observed that one or more steel companies use a hollow duct bank with hollow tile in the center for ventilation, the ducts 2 wide all around. If the ventilation is sufficient, the inside ducts are about the same as the outside ducts, from the standpoint of heat dissipation.

J. FARRINGTON: There are just a few questions I would like to ask. Mr. Rosch has given us a very good insight into cable design, and conditions to be considered. I would like to ask him if his company makes a cement for potheads, and what range of

temperature it will stand without cracking. Also whether they make a cable that can be used for both aerial and underground surves, and if that cable is free from any jute or filler material that will absorb moisture. Also if they make potheads for both power and control cables that will stand up under water pressure. Also has his company heard of a conduit being made waterproof and filled with oil for conducting the heat away.

F. L. AIME: There are several manufacturers who can supply such a compound which is quite satisfactory. It should be dense, plastic over the entire operating range (low temperature susceptibility) so that cracks will not develop, low coefficient of expansion, and be of such a constituency as to adhere closely to the side walls of the pothead or joint and of the conductors inside. The best grade materials will withstand moisture exceedingly well. Their temperature operating range is usually far beyond that of the cable itself. Its performance under water pressure depends more on the correct design of the terminal to obtain water-tight construction. However, many insulating compounds will prevent access of moisture to vital parts.

The usual procedure is for each company which sells joint and pothead materials to furnish instructions for their installation in accordance with their design and in accordance with the materials furnished by them, with which to assemble these joints or potheads. The practice among all such cable companies furnishing these materials is pretty much the same, but varies somewhat in detail, and therefore it is better to obtain these instructions from the manufacturers, unless your company has an established procedure which is known to be satisfactory from previous experience. Our company furnishes a list of all the items enclosed in the package, with each unit package of material for pothead installations. Jointing instructions usually are forwarded either with the jointing materials or separately, depending on the individual case. There are some published instructions available in one or more accessory catalogs.

S. J. ROSCH: Answering Mr. Farrington's question regarding types of cables for overhead and underground use. There are a number of constructions that are satisfactory, depending of course on the combination of conditions to be met.

a. The old reliable lead-covered cable has been used for many years for both aerial and underground installations.
b. The non-metallic armored cables whose outer covering is designed for both underground and overhead use.

These cables of course must be able to withstand alternating heat and cold, moisture and dryness, the sun's rays, and in some cases, vibration. In the latter case, as will be noted in the paper, either an alloy lead sheath should be used, or a non-metallic armored cable without any lead sheath at all.

In the non-leaded, non-metallic armored types, rubber-insulated conductors can be used usually up to 5,000 volts, with rubber fillers and with a rubber jacket if desired. Control cable also is furnished with rubber fillers and rubber jacket. Both constructions are free from any jute or similar fillers. For aerial cables, a suitable saturated braid usually is provided over the rubber jacket to protect it from sun and weather. This braid construction also is very suitable for underground use.

MEMBER: There is one question I'd like to ask. As regards cables which have been installed, say, thirty years ago, what would be the advice of the authors of this paper as to having a system of replacement or is there any history or any experience in time that the life of a cable is good for?

S. J. ROSCH: Once the cable is manufactured, of course its characteristics can not be changed. It seems, therefore, that about the only thing that could be done is to derate the cable, whose new current-carrying capacity is based on calculations using the new ambient temperature of the earth at that point.

MEMBER: Lead cables which have to go through manholes are very often protected by fireproof plaster of some sort. I was wondering if there was any experience with that fireproof plastering to lead—that is, I was wondering if anyone has ever had any experience with lead or maybe something else of a similar sort to the experience with fireproof plastering?

F. L. AIME: General practice now is to apply a grease to the exterior of leaded cables, especially large ones, to assist in pulling them in ducts and to supply the proper lubrication. Soapstone and other materials also are available, but none of these have proven to have as low a coefficient of friction as grease.

Where cables are pulled in ducts, the manhole should be rigged with a snatch block, on the far side from the duct mouth, in order that the pulling rope will come directly out of the duct, then up through the manhole to the pulling device, which usually is on the surface or floor. The reel should be located preferably so that the pull is downhill through the duct. When manholes are difficult, the cable is protected by feeding it down through a flexible steel hose of large diameter, long enough to reach from above the manhole entrance, down to the duct mouth.

The braid or woven coverings on cables for conduit or duct installation are saturated and finished to provide a moisture-resisting and flame-retarding covering and coated overall with mica flake or a slipper wax to prevent sticking and to render the cables more easily pulled in. Specifications and orders should preferably indicate the type of installation for which cables are intended. Mica flake or mica flake mixed with talc or soapstone may be blown into conduits or ducts or thrown on the cables during pullling to lubricate the cables. Mica flake is quite helpful in this respect. Upon request, special types of finish, designed for the easiest pulling in conduit systems with many bends, can be furnished.

E. G. SCHLUP: This paper presents a comprehensive study on the subject matter and should be appreciated by those engineers who, for the past few years, have heard lengthy discussions on cable insulation properties such as "stability", "oxygen bomb test", "low-water absorption" and numerous trade name cables. Similar desiderata was published in

various technical papers. Information of the type presented permits the application engineer to make his own cable selection. Varying conditions are always encountered and in almost all instances, the power engineer is not in a position to select the most desirable cable runway. Definite data on cable design and cable insulation properties eliminate established empirical rules and personal preferences.

The paper does not touch a problem often encountered by the application engineer namely, vertical cable rises of both *high and low voltage*. Migration of moisture followed by drying up of insulation resulting in cable failures being the main trouble.

Reference was also made to the high cost of connectors for bus-bar runs. Some recent installations have materially reduced this cost by welding together the joints. Results with reference to conductivity of the joint, as well as mechanical strength, have been gratifying.

The trend of increased cost efficiency of steel, as well as other commodities, demands further improvement of exact cable specification on the part of the application engineer, and further research on cable insulation by the cable manufacturers.

F. L. AIME: If we take 3/c belted type cables in free air for comparison at 40°C ambient, we find a ratio of about 88% current-carrying capacity for V-C insulated cables against 100% for paper, for the same conductor sizes, for 600 volt operation. For 15,000 volt rating, the ratio is approximately 71% V-C to 100% paper.

The comparisons are taken on four sizes of conductor ranging from 4/0 to 750,000 c.m. inclusive, as follows:

	600 Volts			15,000 Volts		
	Paper	V-C	% of Paper	Paper	V-C	% of Paper
3/c— 4/0 —Non-Shielded	246	216	88	216	155	72
3/c—350,000—Non-Shielded	330	290	88	292	206	71
3/c—500,000—Non-Shielded	412	358	87	356	250	70
3/c—750,000—Non-Shielded	522	458	88	450	312	69

For cables in ducts underground, it should be noted that individual installation conditions may change the ratios over quite a range.

It will be remembered that the maximum permissible temperature for paper cables is 85°C for 600 volts, and 75°C for 15,000 volts belted cable; V-C insulated cables have a maximum permissible temperature of 74.5°C for 600 volts and 60°C for 15,000 volts.

A. D. PETTEE: The authors of this paper have modestly limited the scope of the title of their paper to cable engineering practice in steel mills. Actually, they have reviewed in a very commendable fashion the principal problems at low and moderate voltages in any industrial or distribution application of insulated cables.

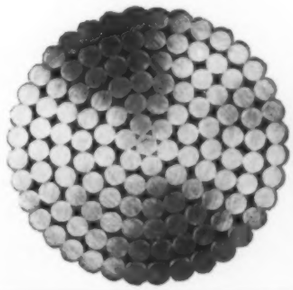
In connection with large size single conductor cables on a-c. systems, the authors correctly point out in their preliminary draft that skin effect and proximity effect become important factors and that special conductor construction such as annular stranding becomes desirable. An alternate conductor stranding known as "segmental" has become increasingly popular during the last few years because of its small diameter and lower cost. As shown in Figure 1 of this discussion, the construction consists of four 90°

FIGURE 1—Comparative diameters and electrical characteristics of 2,000,000 C.M. copper conductor of different constructions.

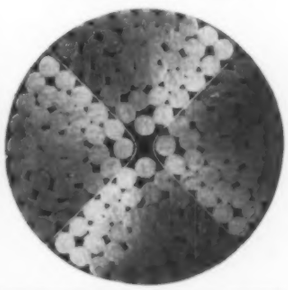
	Usual Concentric Strand	Annular Conductor Strand	Segmental Conductor Strand
Core diameter	0	1.31″	0
Conductor diameter	1.63″	2.11″	1.63″
D. C. Resistance at 65° C. (Ohms per 1000 ft.)	.00622	.00642	.00622
Skin Effect Ratio, 60 Cycle	1.239	1.045	1.039
A. C. Resistance at 65°C., 60 Cycle	.00771	.00671	.00646

Annular Conductor
Large Diameter
Small Skin Effect

Concentric Strand
Small Diameter
Large Skin Effect



Segmental Conductor
Small Diameter
Smallest Skin Effect



sectors cabled together. Equalized reactance of the various layers as a result of the transposition of the individual strands reduces the skin effect to low values, thus making unnecessary the more expensive annular construction.

The diameter of segmental strand is exactly the same as for concentric strand of the same copper cross section.

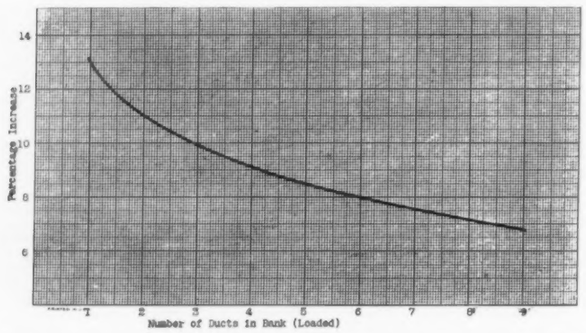


FIGURE 2—Percentage increase in carrying capacity of 3 single conductor cables per duct as compared with 1 three conductor cable per duct.

Under the heading "Single versus Multiple Conductor Cable" in the preliminary draft is found the statement that "the current carrying capacity of three single conductors in one duct is about the same as one three conductor cable of equal conductor size". This is more nearly the case where the number of circuits in a duct bank is large. Where, however, as shown in Figure No. 2, the number of loaded ducts is small, the advantage in favor of the single conductor construction becomes of more importance. With 3 circuits in the bank it is 10 per cent. With this greater carrying capacity of the single conductors it becomes well worth while to consider whether this loading advantage of the single conductor construction does not more than offset the slight disadvantage of using the single conductor cables.

Even in such a complete discussion as the authors have presented, it is, of course, impossible even to touch upon all associated details. One such item is lead sheath alloys, which are assuming increasing importance as the effort to improve the sheaths continues. Figure No. 3 shows important characteristics of plain lead and various alloy leads. Of particular importance is a new lead alloy "Asarco" which has been recently developed by the American Smelting and Refining Co.

Since recent operating statistics show that approximately 82 per cent of the non-inherent failures are due to corrosion, duct mouth wear, lead fatigue, burst sheath, etc.,—that is, to the inability of the lead sheath adequately to protect the insulation during operation; it is obvious that the new alloy, having characteristics tending to minimize the principal causes of cable failure, represents a major advance in the art of cable manufacture.

A special advantage of this new alloy, aside from its extremely favorable physical characteristics, is the relative ease with which it can be run in a lead press in comparison with the numerous difficulties experienced in running the conventional calcium alloy.

FIGURE 3

Alloy	Tensile	Percent Elong. in 8″.	Fatigue* Strength lbs/sq. in.	Lbs/sq. in. Creep 1% 1 Yr.	Brinell Hardness
Common lead	1780 to 1890	20 to 55	400	200	4
Tellurium lead	2150	60	800	<200	5
1% Ant. lead	2800 to 4500	10 to 50	900 (?)	<200 (?)	5 to 10
0.04% Calc. lead	4000	25	1400	500 to 700	8.2
2.0% Tin lead	2800	30	850	200	6
0.08% Cop. lead	1950	40 to 70	700	350	4.5
Asarco Cable lead	4000	25	1500	700 to 800	8.5

*2,000 R.P.M. 25°C. 20,000,000 cycles.

F. L. AIME: The first step to be taken for protection of lead sheath against electrolysis is to see that the cables are properly grounded and bonded, and the second step is to conduct an electrolysis survey to determine the relationship and magnitude of stray currents to the sheath of the cable involved, as well as to any nearby conducting mediums, such as water and steampipes, building steel, railway tracks, etc. A regular procedure for conducting an electrolysis survey is available and can be furnished upon request.

For protection against corrosion, several methods of procedure are available, and this is too long a subject to discuss in detail here. One of the principal sources of corrosion of lead sheath in ducts is due to presence of corrosive waters. If these can not be kept outside the ducts and manholes, it may be necessary to cover the lead sheath with protective wrapping. Several of these are available, and they usually consist of fibrous coverings suitably saturated with moisture resisting compound. Another simple and very effective method is to apply heavy cable grease to the lead sheath as it is drawn in, or to pump grease into the ducts, thus keeping water from contact with the sheath or excluding it from the ducts entirely. Further details on the subject may be found in the paper.

The principal advantages of an annular conductor on large cables are three:

1. Because of skin effect and proximity effect, the current distribution is much better and the conductor is therefore more efficiently used.
2. The increased diameter of the conductor results in a greater overall diameter of the cable with consequent improved heat radiating characteristics and therefore greater current-carrying capacity.
3. Lower voltage drop.

If annular conductors required for any job are of an unusually large size, it might be a good idea to reconsider as to whether the voltage selected for that circuit should not be higher.

Committee Report

A. I. & S. E. Cleveland Section Educational Program

In carrying out the Educational Program as outlined on the editorial page of the December 1937 issue of the "Iron and Steel Engineer", the Cleveland Section educational committee decided to sponsor a course in elementary electrical engineering. The class of 63 men was selected from employees in the steel mills of the Cleveland Section through the cooperation of the various members of the Association in these plants.

The class was presented by Case School of Applied Science with Professor George Mills in charge and assisted by Professor Putnam. Starting February 8, 1938, this class met twice a week for fifteen weeks with the classes running from 7:00 P.M. to 8:30 P.M. The class work included lectures, laboratory demonstration and home problems with their corresponding discussions.

In selecting the men to attend the course, it was decided advisable to restrict this course from graduate electrical engineers due to the fact that it would be entirely too elementary for a man with such training. A cross section of the men that attended included turn foremen, motor inspectors, electrical apprentices, mechnical apprentices and electrical repair shop men. Of the 63 selected to take the course, seven came from Lorain, Ohio, which is approximately 35 miles from Case School, five from Massilon, Ohio approximately 55 miles away, five from Canton, Ohio approximately 60 miles away, four from Louisville, Ohio approximately 58 miles away and the balance from Cleveland.

In regard to attendance at these sessions, the results were very gratifying. Of the 63 who enrolled in the course on February 8, 1938, four dropped the course and 59 completed it. Of the 59 who completed the course, eighteen had perfect attendance and of the eighteen who had perfect attendance four came from Lorain, Ohio, one from Massilon, one from Canton and one from Louisville and the balance from Cleveland. The average attendance at all of these sessions was 87½%. The committee has investigated the cases where the attendance was well under the average and found in the majority of cases, absences were due to sickness and night work in the steel mills.

At the last session of the class, Professor Mills gave a test so laid out that the committee could select the outstanding men of the class. Prizes were presented to the five men receiving the highest grades in this test.

During the spring vacation of Case School of Applied Science the educational program received the help of Mr. Ray Mausk through the cooperation of Cleveland Electric Illuminating Company, who presented a talk on illumination for the class.

Based on the personal reactions we have received from the members of the class who completed the course the committee is pleased to report that it was a great success and judging from the requests that have come in from other men desirous of taking the course, the committee is very hopeful that they will be permitted to repeat the course with slight modifications next year.

T. J. ESS, Chairman
J. D. DONOVAN
F. W. LORIG
W. W. SPANAGEL, Secretary

T. J. ESS, Chairman
Cleveland Section

On Wednesday evening, June 1, at the University Club, Cleveland, Ohio, the Cleveland Section of the Association tendered a dinner to those men who were graduated from the course in elementary electrical engineering sponsored by the Cleveland Section of the Association. Presented above is a report of the Cleveland Committee in charge of the Section's educational program. On the following two pages is published a talk given to the graduates by Charles H. Elliott, Assistant Vice President, in charge of operations, Republic Steel Corporation.

W. W. SPANAGEL, Secretary
Cleveland Section

Address by C. H. ELLIOTT before the A. I. & S. E. Cleveland District Section Elementary Electrical Engineering Course

University Club, Cleveland, Ohio, June 1, 1938

C. H. ELLIOTT

▲ THIS is an occasion upon which congratulations are due two groups of men both animated with the same objective.

Congratulations are first due to the 59 of the 63 students who enrolled in this class of Elementary Electrical Engineering. You men who have given up time to your advancement deserve commendation for the regularity with which you have attended classes and for the seriousness with which you have approached your studies. Your group proves that there is no age limit in a search for further knowledge. I have been told that some of you are 20 and some of you more than 50 years old. This proves that among ambitious people, the desire for more education is always present.

Lauds A. I. & S. E. for Sponsoring Educational Plan

I also wish to congratulate the Cleveland District Section of the Association of Iron and Steel Engineers for their foresight and energy in establishing this course.

I can think of no finer objective than to make learning available to more people. In this project which the Cleveland District has undertaken, it is performing a function which should bring to it the gratitude of the entire community.

It's my opinion that you students chose wisely when you decided to look for more information regarding that most mysterious of all natural forces—electricity. It's only during the past few years that we have really learned anything about electricity—what it does and what we can do with it.

Up to relatively recently, the power used in our plants was generated by steam engines. Today, in place of a single power plant we have motors, frequently attached to individual machines. As a result, there is an increasing demand in our industrial plants for men who understand electricity and its behavior.

This is true in every industry, but especially so, I think, in the one with which I am most familiar—the steel industry. As one goes through that modern industrial giant, the continuous strip mill, one is impressed with the fact that literally hundreds of motors are required to operate the intricate machinery which turns out strip steel at the amazing speed of about 25 miles an hour. Obviously, more motors mean more electricians.

But this reliance upon electric power in the steel industry is not confined to the continuous strip mill, but is to be found in every department and operation. As a result of this constantly increasing use of electric power, I am convinced that the opportunities which will present themselves to you men will increase measurably because of the course of study which you have just completed. These opportunities apply to every one of you whether you are workmen in the mill or foremen. Watch for them. Take advantage of them when they come. And build your future on your increased education.

I hope, however, that none of you will feel that you have reached the end of your educational possibilities. As a matter of fact, in completing this Elementary Course you have only begun on a great voyage of discovery. People are fond of saying nowadays that the world's discoveries are all completed. There is nothing new to find out.

True, there are few parts of this old globe that we don't know something about. But in the world of the mind, or the brain, there are vast unexplored territories before every one of us. Every unopened book is as interesting and mysterious as an unexplored country was 200 years ago. There is as much to be found out—as much to be learned—from these unopened books as there was for the early adventurers who struggled through unknown wilderness.

Students Should Take Advantage of Educational Facilities

So I hope that as you have completed this Elementary Course you will be encouraged to take advantage of the fine educational facilities which Cleveland has offered and pursue your studies into new and equally interesting fields. We all work during the day, but there are many opportunities in Cleveland to attend night courses, through which you can round out your education and fit yourselves more perfectly for the type of work in which you are most interested and

which will bring you more rapid advancement. I grant that it takes a lot of courage and persistence to attent classes after you have completed a hard day's work, but you men, in completing this 15-week course, have already demonstrated that you have this courage and this persistence. So why not follow through on the path that you started and continue the work which you have so ably begun. In addition to the definite knowledge which you will get from such classes, you will develop the persistence which I just mentioned.

Persistence, in my mind, is one of the most important traits that any man who wants to get ahead can have. As you look around you in the plant where you work you will find men of all types occupying executive positions. Their personalities, their mental equipment and their training are all different. But they do have one trait in common, and that is persistence. That means that when they attack a problem they carry it through to the end, no matter how tough the going may be. The persistent man does not give up easily. If he can't find the answer in one direction, he looks in another and he keeps on looking until the solution is at hand. In my experience I have found that this quality takes any man who really wants to get along, a good way up the ladder of success.

You men, therefore, who continue the education which you have so ably started will demonstrate to those who in turn are your superiors that you possess the persistence which is such an important element in any man's character.

Time and Effort Expended Will Pay Dividends in Later Years

You may very well ask, "Where will this all take me in the end? What will I get out of giving up hours of my life to further study?" I know that the vast majority of men prefer to take life easy when they finish the day's work. I know that they have their pleasures and avocations that have first call on their time when the day's job is done. Because there are large numbers of men like that, there are greater opportunities for those of you who take the other road and continue to improve yourselves.

Chances for Advancement in the Steel Industry Are Numerous

Unthinking people are apt to say loosely today that there are no opportunities in industry for the young man. I say they are wrong. Every executive in the company for which you work is some day going to outlive his usefulness. That applies not only to the company for which you work, but to every business organization in the country. One of these days, these executive jobs, whether they be foremen, superintendent, general manager, or president, must be filled by someone other than the men who fill them today. Today's executives aren't going to work and live forever. Every job higher than yours, therefore, means an opportunity for you to achieve greater success and greater well being. Fix your eyes on the job just above you and work for it, knowing that someday it's going to be vacant and some day a successor to the present incumbent is going to be chosen. If you have the skill, the training, the education, the executive ability, to hold that job, you are going to be in mind for it. So don't feel that the hours that you may put in, in further study, are wasted hours; but feel rather that they are stepping stones leading to a better job and to a more successful career.

Hard Work and Sacrifice are Necessary to Obtain Objective

I am a strong believer in the idea that most men, with any kind of a break, get about what they want. A lot of people think they want to reach certain objectives, but they aren't willing to sacrifice and to give up the easier things of life to reach those which are the result of genuine struggle and effort.

If the men in this class, therefore, really make up their minds that they want to progress, that they want something better than they may have today, whatever that may be, I think that unless the breaks are all against them, they will probably reach that objective. I have heard a lot of people who said they wanted this, that, or the other thing—but who wanted it handed to them on silver platters and didn't want to do the necessary hard work to get it. You men have demonstrated that you are willing to do some of that work—that you are willing to go out and devote time and energy to getting what you are after. That's why I think that, provided you keep on as you started, you will all have a real chance to get farther in the organizations in which you work than you are today.

Failure Often Due to Lack of Aggressiveness

It may seem to some of you that I have devoted virtually all of this short talk to preaching a sermon. If I have, it is because I feel very deeply on this whole question. I have seen so many men who should have reached high places, stop far short of their logical objectives because they just didn't have the guts to go ahead. I have been disappointed in so many men in this particular, that I can't help but talk as I do when I am with a group like this, who are demonstrating their willingness to sacrifice hours of potential pleasure to hours of profitable study.

I hope that every one of you will see your way clear to continue on the road which you have started to travel, and that as you increase your knowledge, you will find not only a profitable return but a definite pleasure in knowing more about the things around you. In your journey along this road to opportunity, I want to wish you the very best of luck.

NEW BLOOMING MILL PUT INTO OPERATION AT GREAT LAKES STEEL

▲ On Monday afternoon, May 23, one of the latest additions to the Great Lakes Steel Corporation's plant at Ecorse, Michigan, was put into operation by George R. Fink, President, in the presence of a large gathering of executives and operating men.

This mill, which is a 46″ reversing blooming mill, driven by a 7,000 hp. motor, was successfully put into operation at 2:35 P. M. This mill has a nominal capacity of 1,500,000 tons a year.

The first ingot rolled was 26″ x 47″ x 72″ long, and the first slab produced was 43½″ x 5½″ x 16′ 6″ long weighing 12,580 lbs. This ingot was followed by another and larger ingot 22″ x 66″ x 72″ long and rolled into a slab 60¾″ wide by 4½″ thick. The first slab produced from this large ingot was 16′ 6″ long and weighed 15,010 lbs.

This blooming mill is located in line with the 96″ hot strip mill and was installed primarily to produce wide slabs for this large strip mill. The arrangement is such that slabs can be delivered directly from the blooming mill to the strip mill without any rehandling or reheating. In other words, strip and plate can be produced from the initial ingot heat.

The new mill is housed in a building 100 ft. wide by 250 ft. long. This building has a 41′ 6″ height to the top of the crane rail and is 55′ 0″ high from the floor to the bottom chord of the roof truss.

The mill is served by 75-ton and 25-ton cranes.

The motor room, in which is housed the 7,000 hp, reversing, 600 volt, d-c motor, motor generator sets, control, etc., is 60 ft. wide by 142′ 6″ long. It is of brick construction, with an insulated steel roof deck.

This motor room, like the strip mill motor room, has no windows, all equipment being air cooled and the building ventilated.

Unusually long spindles are used between the pinions and the mill rolls, the mill having a lift of more than 86″ and the screwdown operates at a speed of 360″ per minute.

The screwdown has a Ward-

New 46″ blooming mill installed by Great Lakes Steel Corporation primarily to produce wide slabs for the 96″ hot strip mill.

Motor room, 60′ x 142′ 6″, housing the 7,000 hp. reversing 600 volt d-c motor, motor generator sets, controls, etc.

Shear for cropping slabs with a capacity for cutting 6″ thick by 42″ wide slabs. Slabs 21″ in length may be cut on this shear.

Leonard control, and Ward-Leonard control is also used on the front and back mill tables, manipulator, and slab shear.

On account of the high speed of this mill, unusual precautions have been taken to properly lubricate the equipment. For the screwdown a special oil recirculating system is provided. An independent recirculating lubricating system has also been provided for the pinion stand. All of the table rollers, bearings, and auxiliary equipment are lubricated by several automatic grease lubricating systems.

The slab shear has a capacity for cutting 6″ thick by 62″ wide slabs.

The crops from the slab shear are dropped on an underground conveyor, which carries them to the outside of the building, where they are discharged into a crop pit. This crop pit is served by an overhead electric crane, with magnet, for handling the crops from the pit to railroad cars.

The slab shear is equipped with a motor-driven gauge, permitting the cutting of slabs having a maximum length of 21 feet.

The table from the slab shear is equipped with a 25-ton scale so that each slab is weighed at the shear after being cut to its proper length.

From the shear the slabs are transferred across the building to the slab yard, which is adjacent to the mill building. This transfer is approximately 100 ft. center to center of tables.

From the slab transfer tables the material is delivered to pilers, from where it is delivered either directly to the slab heating furnaces or handled by overhead cranes and stored in the slab yard.

When viewing this installation, one is impressed with the completeness of the electrical and mechanical installation and the nice manner in which this latest installation fits into the general scheme for the wide strip mill.

The mill and tables were built by Mesta Machine Company and the motors and electrical equipment were furnished by the Westinghouse Electric & Manufacturing Company.

The foundations, buildings, and auxiliary equipment were designed and installed under the direction of the Great Lakes Steel Corporation's engineering department.

SUPER ELECTRIC TRUCK BATTERY

▲ Another super-type of electric industrial truck battery is announced by The Electric Storage Battery Company, the second within the past six months. This newest battery is the greater Exide-Ironclad Type "MEH", the first shipment of which left the Exide plant in Philadelphia a few weeks ago.

This battery has capacity enough to provide power and speed to operate trucks of 30,000 pounds or more capacity for 12 or more hours on one charge. It has more cells and a larger number of plates per cell, and consequently more power, than the Type FLM, which was announced several months ago as "the world's largest battery for electric material handling". It does not, however, supersede the FLM, as both batteries were designed and built to fill out the line of Exide-Ironclad Batteries, to meet the needs of all industrial truck users.

The new greater Exide-Ironclad Battery of standard assembly with 18 cells, 21 plates, assembled in steel trays, weighs approximately 4200 pounds; is 54⅛″ long, by 25⅞″ wide, by 31⅛″ high, overall. Its capacity is 1,000 ampere hours, or 34.4 kilowatt hours. A 24-cell size, with 21 plates per cell, has a capacity of 45.9 kilowatt hours at normal discharge rate.

In describing the future of this newest Exide-Ironclad Battery, William Van C. Brandt, Manager Exide Motive Power Battery Sales, said:

"The development in the Electric Industrial Truck Industry has been so rapid during the past few years in meeting the demand for trucks of greater and still greater carrying capacity that batteries of the conventional size are far too small to furnish the power and capacity required for these huge trucks of 20,000 to 30,000 pounds load capacity.

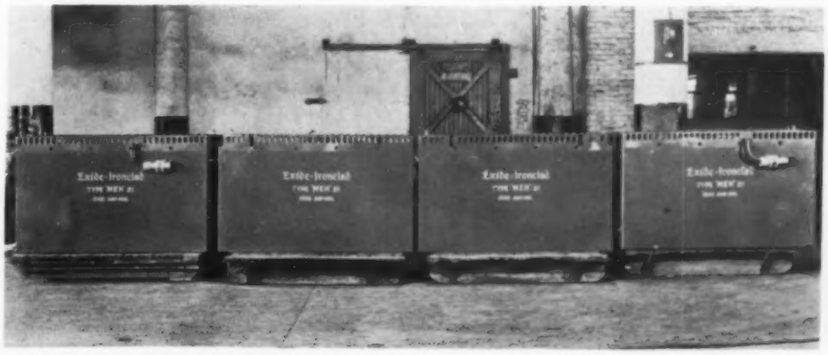
"Some years ago, Exide recognized the trend of this development towards larger trucks, and in anticipation of a new market we developed the high type TLM Exide Ironclad Battery, a type of cell having an increase of 43 per cent kw. hour capacity with no increase in square area of battery compartment. This was the first high type cell, and our expectations were more than realized.

"Just as we anticipated some years ago a market for trucks of 8,000 to 10,000 pounds, we now foresee a market developing, particularly in the steel industry and the automobile industry, for huge ram and fork trucks having a load capacity of 30,000, 40,000 and even 50,000 pounds. In order to be ready for this market, we have developed the new "MEH" Exide-Ironclad Battery in four sizes of cells, 15-plates to 21-plates inclusive, and having a capacity of 700, 800, 900 and 1,000 ampere hours respectively.

"For greater capacity, we have the super Exide Ironclad Battery, FLAM-13 cell, with a capacity of 1080 ampere hours.

"The new MEH fills out the Exide-Ironclad line, making it possible to supply an Exide Ironclad battery of sufficient power and capacity to meet the requirements of any size and type of electric industrial truck for any job. It also enables the electric industrial truck user to obtain dependable battery power and low cost

Super-type of electric industrial truck battery with capacity to provide power and speed to operate trucks of 30,000 pounds or more capacity for 12 or more hours on one charge.



of operation, for which battery trucks are noted, regardless of whether the particular material handling job is that requiring a small truck or the huge super-trucks of 30,000 pounds or more".

STEEL EXECUTIVES INSPECT NEW SLABBING MILL

▲ More than 200 steel executives and technicians recently visited United Engineering & Foundry Co.'s Youngstown plant, where the new 45 x 80 in. slabbing mill stand and its vertical edger for Carnegie-Illinois Steel Corporation's Edgar Thomson plant were set up for inspection. This mill will have an annual capacity of more than 1,000,000 tons and will furnish slabs for the new Irvin works in addition to regular blooms for other uses.

The slabber will handle up to 45,000 lb. of ingots conveyed by motorized ingot car to a turntable and weighing machine. Scales and turntable will operate so that the weight is automatically registered and either end of the ingot can be headed toward the rolls.

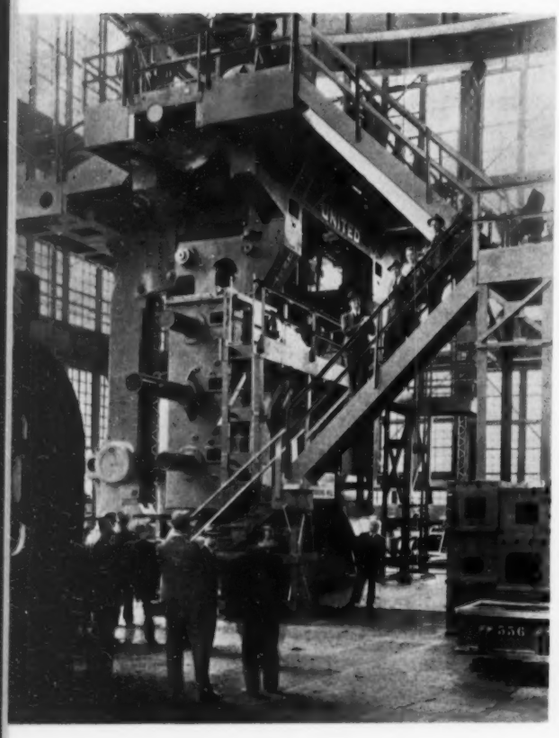
Beyond the approach tables will be two horizontal rolls measuring 45 x 80 in., each driven by a 5000-hp. motor. Two vertical rolls are also part of the slabber and measure 36 in. in diameter. They will be driven by a combination of beveled gear and single helical spur gears. Both vertical rolls are driven by a 3000-hp. reversing motor.

Electrically controlled manipulators will be provided on both sides of the mill. For quick roll changing a motor-operated changing device will be installed. Instead of the conventional practice of keying the drive gears direct to the rolls, the drives for the vertical rolls form separate units which will allow an exceptionally quick and easy change.

Also part of the new installation is a recently developed up-and-down cut shear which will handle up to 8 x 60 in. slabs. Both mill tables, the manipulator, the screw-downs and the shears are equipped with Ward-Leonard controls.

The new slabbing mill is being shipped to Edgar Thomson where erection will be begun immediately. Operations will be well under way by the time the Irvin Works begins to roll strip.

Shop view of the new 45″ x 80″ slabbing mill stand and its edger, being built for Edgar Thomson Works of Carnegie-Illinois Steel Corporation at United Engineering and Foundry Company's Youngstown plant.



MAGNET HANDLES PACKAGED STEEL

▲ Like many other users of sheet steel the Ohio Electric Mfg. Co., Cleveland, Ohio, have deliveries made in bundles which they unload and handle by means of an electric hoist on a monorail.

For years they used chains and could not avoid damaging a number of sheets at each lift.

To unload a shipment of 20 tons required the labor of 3 men for 1½ to 2 hours.

Some time ago they adopted a method of packing which improved the situation somewhat since it kept the bundles flat and made it easier to attach the clamps for lifting. They send a copy of this drawing with each order.

This method of strapping adds nothing to the price of the steel. Our bundles measure 34″ wide by 100″ long and have an average weight of about 5000 pounds.

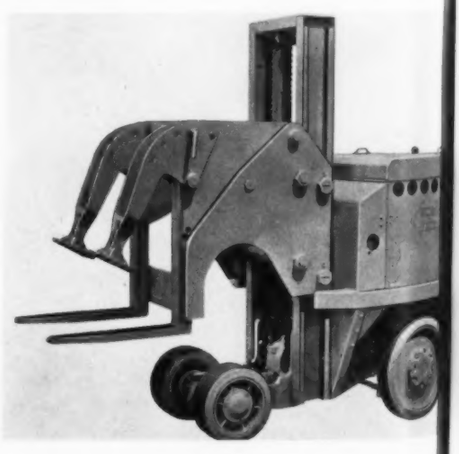
The magnet illustrated above is capable of unloading 27 tons of specially wrapped sheet steel in 39 minutes.

Although they make lifting magnets it took them a long time to realize that they could use one on this job and save enough time, money and damage to pay a splendid dividend upon its cost.

With the magnet as illustrated, one man unloaded 27 tons in 39 minutes including the time required to take the picture.

The weight of the pack and the size magnet can be made to suit varying conditions such as capacity of hoist or crane. The magnet illustrated can handle up to 12,000 pounds.

This electrical industrial truck has a rated capacity of 5,000 pounds and has two wheel drive and four wheel stand.



ELECTRIC TRUCK FOR HANDLING TIN PLATE

▲ Elwell-Parker's Type F-10 truck used for handling tinplate to and from the sorting table, has a rated capacity of 5000 pounds and has two wheel drive and four wheel steer. Steering is by hand wheel through gear reduction.

The trail axle is single heavy forged bar pivoted at the center to permit compensating action in the event of rough runways or floors. Steering arms and rods are above axle for greater road clearance and accessibility.

The drive axle is equipped with an Elwell-Parker, 500 per cent overload, series wound, four pole, heavy duty and high torque motor. Motor is direct connected to free coasting worm and gear. Spur gearing may be supplied upon application.

This truck has four speeds forward and four reverse. The power circuit is closed and broken by a mill type magnetic blow-out contactor.

The tin plate clamps on the F-10 truck are so designed that, as the forks are raised, the clamps automatically lower and firmly hold the tin plate. When not required the clamps may be locked in an upright position.

A solenoid brake on the hoist motor locks load in position unless released by the application of power. Regenerative braking supplements the solenoid brake and returns current to the battery when lowering load. A ratchet protects the mechanism at the bottom of down-travel and an electric clutch protects mechanism at the limit.

This truck bears the Underwriter's seal in testimony to the maker's successful effort to guard in advance against personal injury, loss or damage.

NEW LITERATURE

▲ Johns-Manville has recently revised their booklet: "Johns-Manville Bonded Built-up Roofs", to include information on the latest types of built-up roofing; and now contains within its thirty-six pages more than forty complete detailed specifications.

Illustrating the manner in which the roofing materials are applied to various types of roof decks are several pages of specifications and drawings.

Copies of this book are available upon request to Johns-Manville, 22 East Fortieth Street, New York, New York.

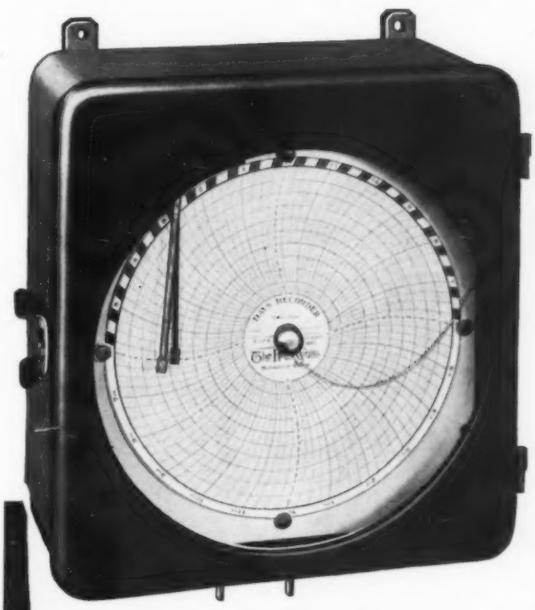
▲ Homestead Valve Manufacturing Company, Inc., of Coraopolis, Pennsylvania, has issued an attractive 48-page booklet, featuring a more complete line of boiler blow-off valves; several new lines of lift-plug valves; more complete dimensions, tables and facts about Homestead valves; and a new line of semi-steel 500 pound O. W. G. (oil, water, and gas) valve for the oil industry. In addition, there are three full pages of suggested uses for valves in all industries, and suggested metals for special service conditions which users find very helpful in solving valve problems.

Anyone desiring a copy of this bulletin, should write to Homestead Valve Manufacturing Company, Coraopolis, Pennsylvania, and ask for Reference Book No. 38.

▲ Leeds & Northrup Company has just issued a new 20-page catalog on "Micromax Frequency Recorders and Indicators". Contents of this book

(*Please turn to page 88*)

REGISTERS DRAFT, PRESSURE AND DIFFERENTIAL



in

SOAKING PITS

•

ANNEALING FURNACES

•

OPEN HEARTHS

•

SLAB MILLS

HAYS "OT" DRAFT RECORDERS

Results in a better product because it gives a correct indication of furnace atmospheres. Built husky enough to stand the severest steel mill conditions yet sensitive enough to register accurately in increments of .0025 in. water. Employs the famous Hays Slack Leather Diaphragm —self sealing—not damaged under sudden excess pressures. Two draft valves, two pressure valves, two differential valves, or a combination of any two of these three valves may be recorded. Or a temperature recorder may be substituted for one of these valves.

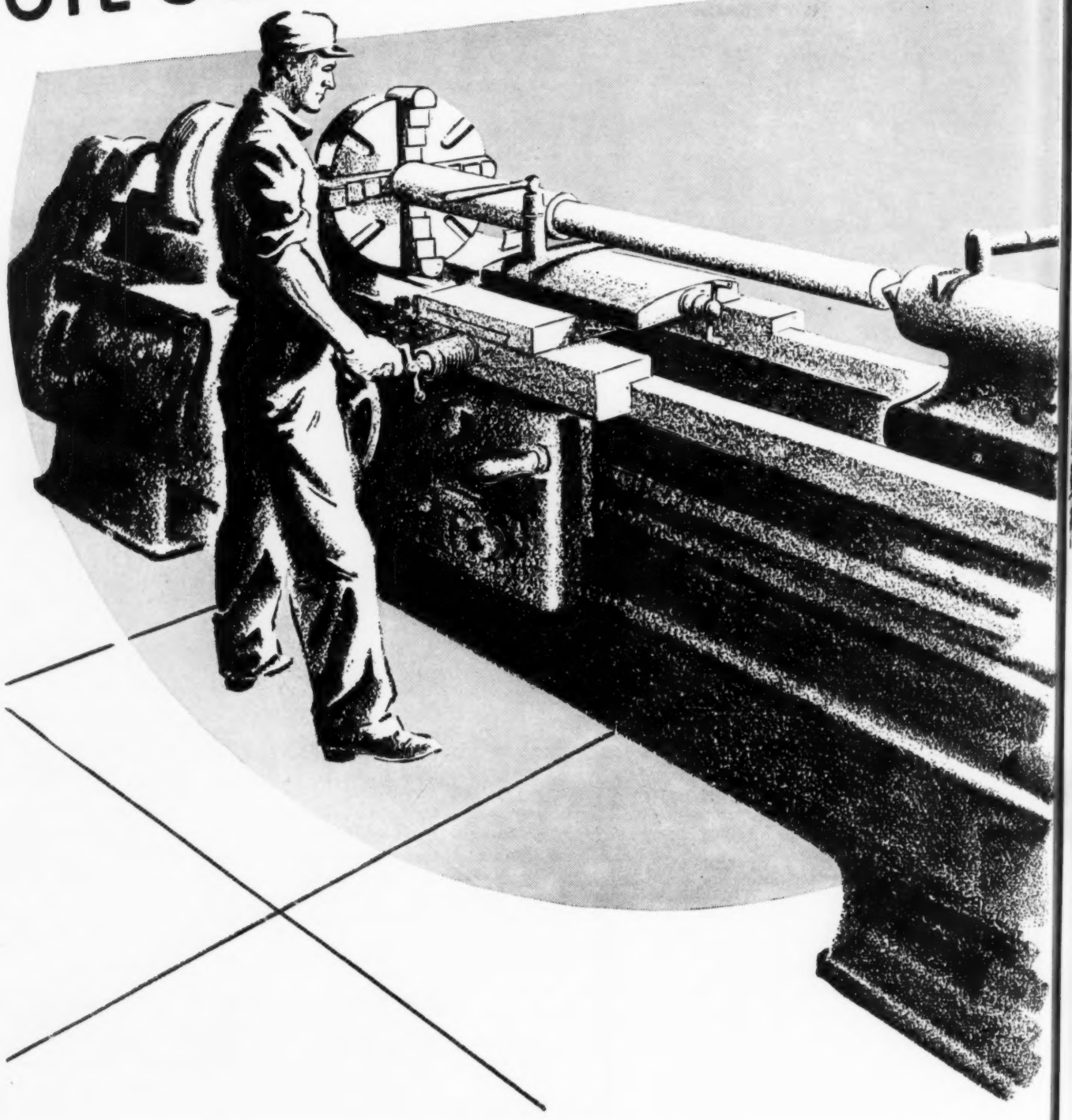
SEND FOR DESCRIPTIVE LITERATURE

The HAYS CORPORATION

SINCE 1901 — COMBUSTION INSTRUMENTS AND CONTROL

MICHIGAN CITY, INDIANA, U.S.A.

"We Stopped paying on our 15 h.p. Lathe by



a 'Shutdown Tax' installing . . . BUSS *Super Lag* FUSES"

"Sure You Can Quote Me" continues Mr. Carl Boyer, Electrical Engineer of Jacobs Aircraft Engine Co., Pottstown, Pa.

"Production on our 15 h. p. lathe was being penalized by fuses blowing on temporary or harmless overloads.

"This hidden tax on our profits had us pretty well fed up as the shutdowns were occurring about four times weekly. Along about Sept. 15th, 1937, we decided to test the claims made for BUSS Super-Lag Fuses. They came through all right—for we haven't had a single fuse blow since we installed them."

If you too, are paying shutdown taxes why not switch to BUSS fuses . . .

Acting too hastily is what often causes ordinary protective devices to shut down circuits needlessly.

When an overload comes along they don't wait to find out if it is harm-charged or harmless. They just jump out from under it and down goes the circuit.

The Super-Lag construction of BUSS fuses steps in to correct this condition.

Dangerous overloads or short-circuits are quickly blocked—but harmless overloads can't scare a BUSS fuse into needlessly closing down a circuit.

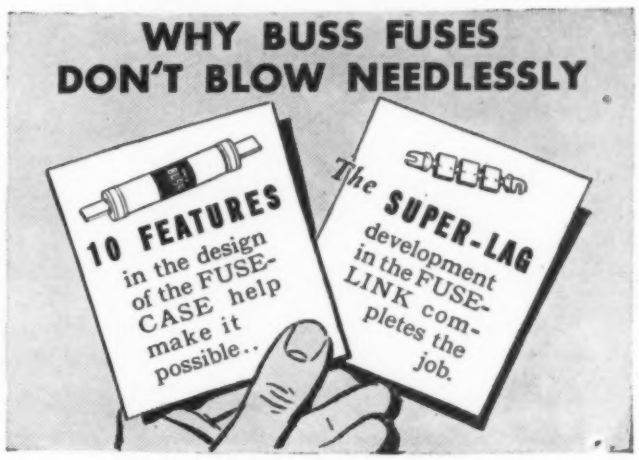
The BUSS fuse waits and decides whether it is necessary to open *to protect equipment*—or—whether it will be safe to hold on *to prevent plunging the plant into a useless shutdown.*

BUSS Super-Lag Fuses are available thru Electrical Wholesalers

Why not take advantage of the superiority of BUSS fuses by passing the word along that all purchases and stock records should call for BUSS Super-Lag Fuses?

If you would like more information on other money saving features of BUSS fuses ask for a free copy of the Rb book on fuses.

BUSSMANN MANUFACTURING CO.
2536 W. University St., St. Louis, Mo.
Division McGraw Electric Company


WHY BUSS FUSES
DON'T BLOW NEEDLESSLY
10 FEATURES
in the design of the FUSE-CASE help make it possible..
The SUPER-LAG
development in the FUSE-LINK completes the job.

(*Continued from page 85*)

include measurement of frequency in power station; method of measurement; and choice of frequency-measuring apparatus. Also listed are descriptions of several products of this company, and illustrations of various modern installations.

Readers desiring a copy of this booklet may obtain same by writing to the Leeds & Northrup Company, 4934 Stenton Avenue, Philadelphia, Pennsylvania, requesting Catalog N-57-161, 1938.

▲ Dings Magnetic Separator Company announces the publication of an attractively illustrated brochure dealing primarily with high intensity lifting magnets. Other types of magnetic separators are also shown.

If you wish to obtain a copy of this brochure, address: Dings Magnetic Separator Company, Milwaukee, Wisconsin, and request catalog Number 22.

▲ De Laval Steam Turbine Company announces the availability of a profusely illustrated catalog describing small steam turbines for driving auxiliary machinery, such as generators, pumps, fans, etc. These turbines are of the velocity stage type and, when operated at suitable speeds, as in connection with high speed machinery or by the use of speed reducing gears, and exhausting to back pressure, show good efficiency. The design has been specially adapted to the use of high pressure, high temperature steam by locating the steam chest in the upper part of the casing cover, where it is above and well removed from the bearings.

This booklet, known as catalog C, is entitled: "Velocity Stage Turbines", and may be secured by writing the De Laval Steam Turbine Company, at Trenton, New Jersey.

▲ The Buromin Company has issued an attractive folder describing Buromin and Hall methods of boiler water conditioning to keep boilers free from scale, and to protect them against wet steam, corrosion, and embrittlement of the boiler metal. Also included in this folder is the story of Buromin research, and its connection with Hall Laboratories, Inc.

Copies of this may be obtained from the Buromin Company which is located in the Bowman Building, Pittsburgh, Pennsylvania.

▲ M. H. Detrick Company has published a very attractive manual, profusely colored and illustrated, describing the Detrick furnace design. This book gives the principles of construction and applications, for all types of furnaces, of Detrick walls and arches. Included in its pages is a description of the evolution of furnaces, several pictures and diagrams of actual installations, and some valuable charts giving solutions to various engineering problems.

If you would like to obtain a copy of this book, we suggest that you write the M. H. Detrick Company, 712 Empire Building, Pittsburgh, Pennsylvania.

▲ Farrel-Birmingham Company, Inc. announces the publication of a new 80-page illustrated handbook. This handbook discusses herringbone gears and their advantages for transmitting power and transforming speed between parallel shafts. It explains the introduction of the Sykes process for generating continuous herringbone teeth and its development by the Farrel-Birmingham Company. The new catalog contains twenty illustrated pages describing a complete series of gear units of the speed reducing type, accompanied by tables of horsepower ratings, service factors, overhung load capacities, dimensions and weights. Similar descriptive and engineering data are given on speed increasing units, vertical reduction units of the horizontal shaft type and right angle vertical shaft drives.

Complimentary copies may be secured by plant executives and engineers who write to Farrel-Birmingham Company, Inc., 344 Vulcan Street, Buffalo, New York, for Catalog 438.

▲ The Pyle-National Company has issued a pamphlet describing "Vapor-tight-Industrial Lighting Fixtures". This booklet shows how these fixtures are particularly suited to services where dirt, dust, gases, moisture, or other severe conditions are found. Several pages are devoted to the wide range of types available.

This book may be requested by addressing the Pyle-National Company, 1334 North Kostner Avenue, Chicago, Illinois.

▲ Jefferson Electric Company has published a pamphlet suitable for attaching in looseleaf notebook file. The booklet describes and illustrates "Jefferson Fustats". Application and operating characteristics are discussed with specific data included on the 15 to 30 ampere sizes for circuit protection, and the 0 to 14 ampere sizes for motor, appliance, and circuit protection.

The Jefferson Electric Company is located at Bellwood, Illinois.

▲ Lee Wilson Engineering Company has just issued an attractively designed folder describing a new Wilson annealing furnace for wire or strip. This furnace an exclusive development of the Lee Wilson Engineering Company, is illustrated in a very interesting manner, with pictures and charts.

Copies may be secured from Lee Wilson Engineering Company, 1370 Blount Street, Cleveland, Ohio.

▲ Bailey Meter Company has published a brochure on "Bailey Boiler Meters", which contains an analysis of 7,000 combustion tests made during the last twelve years on all types and sizes of boilers including a full range of fuels and methods of firing.

This brochure shows graphically the average percentage of excess air with which various classifications of boiler units are operating in actual practice. It also shows the percentage occurrence of limiting factors in reducing excess air for combustion under boilers with various types of firing and furnace wall construction. These factors are named as: (1) Furnace maintenance. (2) Carbon monoxide. (3) Smoke. (4) Ash pit loss or combustible in flue gases.

Requests for copies of this book should be addressed to: The Bailey Meter Company, 1050 Ivanhoe Road, Cleveland, Ohio.

▲ The Electric Controller and Manufacturing Company has issued a booklet written by H. L. Wilcox, assistant chief engineer of the Company. The title of this interesting bulletin is: "We Raised Our Power Factor and Save $900 a Year". Any user of a large number of motors, according to the book, will find much valuable information in its pages, and also helpful suggestions for checking to see if poor power factor is present in a system. The Electric Controller and Manufacturing Company will furnish one copy to every inquirer free of charge, but in the event that a large number of copies are requested by one individual, there will be a slight cost to cover the cost of preparation and mailing. This company is located at 2700 East 79th Street, Cleveland, Ohio.

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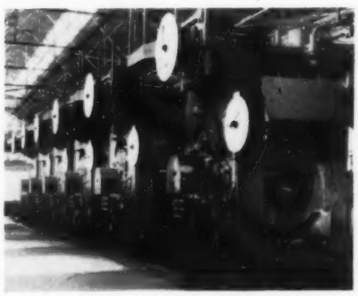
on its first trip in 1860 accomplished the tremendous task of traveling 2,000 miles in a little over 7 days. Today the same distance may be traversed by air in as many hours.

YESTERDAY'S PROBLEM IS TODAY'S ACHIEVEMENT



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ITEMS OF INTEREST

Ross L. Leffler, formerly manager of industrial relations, Pittsburgh district, has been appointed director of industrial relations, for Carnegie-Illinois Steel Corporation. Mr. Leffler enters the augmented position with a record of twenty-eight years employment by Carnegie-Illinois Steel Corporation, and a predecessor concern, Carnegie Steel Company, which he entered in 1910, as a time taker at Duquesne Works. After serving in several positions at Duquesne, including rolling mill superintendent and superintendent of personnel, Mr. Leffler was appointed manager of industrial relations, Pittsburgh district, in October 1935.

▲

George P. Wardley will be assistant director of industrial relations for Carnegie-Illinois Steel Corporation, Pittsburgh, Pennsylvania. Mr. Wardley began his service record with United States Steel Corporation subsidiaries in 1907, with the H. C. Frick Coke Company, in Pittsburgh. He successively worked in supervisory capacities at the Joilet, Illinois, coke by-product plant and South Chicago plants of the former Illinois Steel Comapny, another predecessor of Carnegie-Illinois, until his present appointment. Prior to this appointment, Mr. Wardley was superintendent of industrial relations at the South Chicago Works.

ROSS L. LEFFLER

Floyd A. Beatty has resigned as senior vice-president, in charge of plant operations for the Lewis Foundry and Machine Company, a division of the Blaw-Knox Company, and expects to take a much needed rest. Mr. Beatty was educated in mechanical electrical, and structural engineering, and has had considerable experience in machine shop, foundry, and patternshop operations. After serving an apprenticeship with the Indiana Foundry and Machine Company, he went to Standard Plate Glass Company, and became assistant master mechanic in charge of machine shops, power houses, and all maintenance work.

In 1915, Mr. Beatty entered the steel business going to the Forged Steel Wheel Company, in Butler, Pennsylvania, now known as the American Rolling Mill Company, as a plant engineer. From the Forged Steel Wheel Company he went to Spang and Company, becoming chief engineer. From Spang and Company he went with the Jones and Laughlin Steel Corporation as a designing engineer.

In 1925, he became associated with the Lewis Foundry and Machine Company, and served successively as chief engineer, operating vice-president, and vice-president in charge of engineering and machinery sales. In his connection with the Lewis Foundry and Machine Company, Mr. Beatty was responsible for all developing, estimating, proposals, and quotations, in addition to machinery sales. These duties put him in touch with practically all of the engineers and operators of the steel companies, as well as the brass, copper, aluminum, and zinc companies.

The Three High Sheet Roughing Mill, which Mr. Beatty developed made him many friends in foreign countries, including England, Sweden, Australia, Canada, India, Russia, and Japan. He engineered sold, and supervised construction of Three High Sheet Mills for all these countries.

Mr. Beatty is a member of the Association of Iron and Steel Engineers and the American Iron and Steel Institute.

▲

Anders G. Ericson has been appointed chief engineer of the Homestead Works of the Carnegie-Illinois Steel Corporation, Pittsburgh, Pennsylvania. Mr. Ericson, who succeeds A. W. Soderberg, retired, came to the United States from Sweden in 1921, and joined the United States Steel Corporation organization at Homestead in 1924 as a draftsman. He has been assistant to the chief engineer since 1935.

▲

Arthur V. Wiebel was made assistant chief engineer of the Homestead Works of the Carnegie-Illinois Steel Corporation, Pittsburgh, Pennsylvania. Mr. Wiebel, succeeding Anders G. Ericson, came to the company from Carnegie Institute of Technology in 1933, and has been on the engineering staff in the Pittsburgh office since 1937.

GEORGE P. WARDLEY

F. A. BEATTY

J. A. CARTER

Joseph A. Carter, since March, 1936, general superintendent of the Pittsburgh Steel Company, Pittsburgh, Pennsylvania, has been elected vice president in charge of operations, and a director of the company. Born in Harvey, Illinois, in 1893, Mr. Carter was graduated from Rose Polytechnic Institute in 1916. In that year he began as third helper in the Lowellville, Ohio, open hearth department of the Sharon Steel Corporation. In 1929, he was made superintendent of the open hearth department at Lowellville; in 1926, he was promoted to assistant general superintendent of the Lowellville Works. In 1931, Mr. Carter was elevated to general superintendent, a post held until last March when he was moved to Pittsburgh, Pennsylvania.

▲

Howard Dingle, president of the Cleveland Worm & Gear Company, and Charles F. Goedke, head of the Ganschow Gear Company have been elected by the American Gear Manufacturers Association to serve as president and vice-president, respectively, for the coming year.

▲

George A. Higgins was appointed assistant manager of sales of the bar, strip and semi-finished materials division of the Carnegie-Illinois Steel Corporation, Pittsburgh, Pennsylvania. Mr. Higgins for three and a half years has been assistant manager of sales, Pittsburgh district. Prior to that time he served as sales representative, chiefly in the Pittsburgh district. He has been with the Carnegie company since 1919, when he returned from the World War Aviation Service.

▲

Charles M. White, recipient of the American Iron and Steel Institute medal for 1937, is vice president in charge of operations of Republic Steel Corporation, Cleveland, Ohio. Educated at Maryland State College, and successively a lumberman, tanner, telephone lineman, and railroad construction worker, in 1913 he became a machinist's helper at the American Bridge Company, in Ambridge, Pennsylvania. He progressed to millwright helper in a sintering plant, and eventually was promoted to superintendent. Going with the Jones and Laughlin Steel Corporation, he progressed to general superintendent of the Aliquippa plant. In 1930 he went with Republic as assistant vice president in charge of operations, and in 1935 he was made vice president.

▲

E. J. Parsons was made superintendent of the open hearth and rolling mills at the Vandergrift, Pennsylvania, Works, Carnegie-Illinois Steel Corporation. Mr. Parsons was formerly superintendent of the open hearth at the Vandergrift plant.

▲

James M. Bortz was appointed assistant to general superintendent of the Carnegie-Illinois Steel

CHARLES M. WHITE

ADVERTISING PAGES REMOVED

Corporation, Vandergrift, Pennsylvania. Mr. Bortz formerly was superintendent of the bar and blooming mills at that plant.

▲

A. J. Jennings has been appointed general sales manager of the Cleveland Worm & Gear Company and of its affiliate, the Farval Corporation, manufacturers of centralized systems of lubrication. Mr. Jennings has been directing Farval sales for many years, coming to Cleveland in 1932 when the business was purchased by the gear company and moved from Battle Creek, Michigan. Assisting Mr. Jennings, will be S. L. Eastman, who has been sales representative for Cleveland Worm & Gear Company for several years, and C. R. Burrell, who also came to Cleveland with Mr. Jennings in 1932.

▲

W. T. Schaup has been appointed as service engineer by Basic Dolomite, Incorporated of Cleveland, Ohio. Mr. Schaup has a long record of service in the Iron and Steel Industry.

Mr. Schaup, with several years experience in the refractory business, will now be associated with Hugh D. Largey, regional sales manager of Basic Dolomite, Incorporated, with offices at 1714 Keystone Hotel Building, Pittsburgh, Pennsylvania.

▲

J. M. Chapple has been appointed managing director of Lincoln Electric Company (Australia) Pty., Ltd., recently established at Alexandria, Australia. Mr. Chapple will be in charge of manufacturing, sales and advertising of the new company. For thirteen years he has been associated with Armco International Corporation, most of the time in foreign service.

Mr. Chapple was born at Ashland, Wisconsin, where he attended grade and high schools. He attended the University of Wisconsin, and was graduated from Princeton University in 1923.

Obituaries

Richard C. Lewis, sales engineer of the Farrel-Birmingham Company, Inc., Ansonia, Connecticut, was killed May 24 in an airplane crash near Cleveland, Ohio.

At the time of his death, Mr. Lewis was manager of the rolling mill sales division of the Farrel-Birmingham Company, in charge of sales of rolling mill equipment and roll grinding machines. Previously, he had been connected with the engineering department as division engineer in charge of engineering of rolling mills, metal working machinery, roll grinders, and other heavy equipment. Mr. Lewis was experienced in sales and engineering on practically all products of the company, and had been granted a number of patents for mechanical devices he had invented.

Mr. Lewis was born in Ansonia, Connecticut, on December 20, 1896. He received his early education in the Ansonia public schools, and was graduated from Worcester Polytechnic Institute in 1919, after serving in the United States Army during the World War. He entered the employ of the Farrel Foundry and Machine Company as a draftsman, after his graduation.

Mr. Lewis was a member of the Association of Iron and Steel Engineers, the American Society for Metals, and the American Society of Mechanical Engineers.

▲

J. F. Kohlmorgan, who was chief engineer of the Alan Wood Steel Company, Conshohocken, Pennsylvania, since 1924, died on May 28, 1938. Mr. Kohlmorgan, prior to his association with Alan Wood Steel Company, was in the engineering department of Inland Steel Company, and Interstate Iron and Steel Company, both of Chicago, Illinois.

Mr. Kohlmorgan was a member of the Association of Iron and Steel Engineers.

A. J. JENNINGS

W. T. SCHAUP

R. C. LEWIS

J. M. CHAPPLE